ORGANIC AGRICULTURE

A Global Perspective

Editors: Paul Kristiansen, Acram Taji and John Reganold

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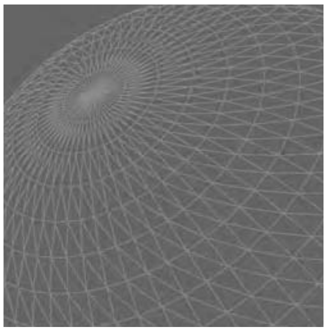

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Foreword

Professor Ulrich Köpke, Institute of Organic Agriculture, University of Bonn, Germany; and President, International Society of Organic Agriculture Research

At first glance, the title of this compilation, *Organic Agriculture: a Global Perspective* is puzzling: 'global perspective' is a key phrase used in contemporary political and economic discourses, discourses which do not necessarily focus on organic agriculture.

Yet, once one has eventually discerned the various meanings and connotations of the phrase, speaking of a 'global perspective on organic agriculture' seems more than appropriate, and indeed, promising. After all, organic agriculture seeks to pursue a holistic approach, encompassing not only farming as such but also the wider implications it has for factors such as social relationships and the environment.

This book however, also does justice to its title in a very different way: it is 'global' in that various contributions elucidate the subject in a general way. Furthermore, the book offers different approaches from different regions of the world, as represented by a host of international authors. The subject is thus dealt with 'globally' in yet another sense; by encompassing many regions of the world, the perspectives albeit shaped by the diversity of regional and local sites as well as individual authors' points of view concerning the specific strategies of organic agriculture. This highlights once more the principle of organic agriculture as an environmentally sound and site-adapted agricultural approach. Thus, the reader is able to detect specific or individual aspects of organic agriculture within broader and more general accounts, far from generalisation or simplification.

The reader will gain a comprehensive overview through review-like contributions that comprehensively present the state of the art, but also offer fundamentally new and deeper insights. Other, more specific contributions offer both new outlooks or conclusions, and thoughts on the prospects of organic farming and its further evolution.

The further evolution of organic agriculture presupposes intensified education and training in all areas of knowledge and capacity building, especially when it comes to participation and the fostering of social competency. Thus, the book is positioned at the intersection of research, education and practice.

The further development of organic agriculture, which originally developed out of agricultural practice, is impossible without solid scientific grounding. Nevertheless, insights and experience remain without implementation, and therefore effect, if they fail to achieve the target groups' proper reception.

Hence, this book might inspire its readers to continue intensive research in organic agriculture. I hope that it will contribute to the opening up of the scientific community interested in organic agriculture and further enhance knowledge transfer. Practicing readers, however, might receive ideas and inspiration for modification and improvement of their techniques. Lastly, this book might help to intensify the dialogue concerning the opportunities offered by organic agriculture taking place with officials in politics and administration.

May this book do justice to its ambitious title and find a good reception among its readers.

Preface

It is a historically opportune time to review organic agriculture. Alongside the burgeoning production and trade in organic produce, increased interaction between researchers and organic producers has led to comparable growth in the production of organic knowledge. For example, new research centres have been established in many countries and there is increasing support from private and government funding agencies for organic-specific research. Growing numbers of peer-reviewed journals have been publishing organic agriculture-focused research, many organic conferences have been held around the world and the International Society for Organic Agriculture Research (ISOFAR) is now supporting organic researchers and promoting improved methodologies for researching organic systems.

These activities have created considerable knowledge on organic agriculture, and the opportunity for evaluation. There is now sufficient, robust information to begin reviewing the strengths and weaknesses, assessing the extent to which its claims are validated and identifying ways to improve the sustainability and productivity of organic agriculture. Certainly, some of the work needs further verification or repetition for example, over longer time spans, but the quality of research on organic farming systems has been recognised by the top scientific forums such as the journals *Nature* and *Science*.

Despite the impressive growth in the recent past, the outlook for organic farming is not all rosy. The movement has reached a point where there are signs that the large increases in demand may be slowing, contamination by genetically modified crops poses a threat, and criticisms have been raised against certain practices such reliance on tillage and the growing industrialisation of the movement. The organic movement has a history of almost 100 years, with over 50 years of continuous production on some farms. In addition, there has been huge growth of the organisations that underpin the organic movement and study by mainstream researchers over the last 30 years. Now it is time to evaluate, reflect and revise.

The objectives of this book are to:

- describe and critically review key aspects of organic agriculture such as soil fertility management, plant and animal production, social and environmental issues, as well as training and research;
- maintain a global perspective by drawing on a multinational team of authors and referring to the widest available data in each section;
- combine in one volume the insights of international experts who have direct experience with the organic movement, from on-farm work and teaching to marketing and rural appraisal; and
- provide a unique and timely science-based resource for researchers, teachers, extensionists, students, primary producers and others around the world.

There are five main sections to the book. The first section provides a general introduction to the organic movement followed by reviews of key agricultural production issues such as managing soils, plants and livestock, and breeding plants and animals for organic farming systems. The second section deals with overarching regulatory and management concerns including developing effective and verifiable organic standards and certification processes, as well as economic and marketing considerations. Section three contains chapters addressing the external or off-farm issues, topics that are especially relevant 'beyond the farm gate'. The environmental and social impacts of organic farming are reviewed and differences in food quality between farming systems are also discussed in detail. The fourth section deals with topics related to developing a knowledge base and building human capacity for organic agriculture. The key themes in this section are research, education, extension and training. The final section provides a summary of the key issues and challenges raised in the book.

The book gathers together a range of specialists with direct experience with organic farming over many years. Authors from over a dozen countries in several continents have contributed their knowledge to the book, making it more than just another Eurocentric or North American perspective on organic agriculture. A special feature of the book is a series of five 'Special topics', smaller sections that address key questions or challenges facing organic agriculture. These sections are intended to provide a more detailed analysis of specific issues that cannot be covered as sufficiently in the larger general chapters.

The book is not designed to be a set of production and marketing guidelines or a 'how to do it' manual for organic producers; nor are the reviews intended to be uncritical descriptions of organic principles and practices. Instead the reviews provide an objective and rigorous critique of the issues covered. The purpose is to evaluate, rather than advocate, organic agriculture. Some of the reviews presented may be limited by the lack of available data, especially outside western Europe and North America. The small size of the organic movement and lack of government and business support over several decades have meant that important data sets (e.g. economics of conversion) have not been collected in many regions or at all.

This book is intended to be a unique and indispensable resource that offers a diverse range of valuable information, data and perspectives on organic agriculture at a time when the world community is increasingly aware of the problems of our current agricultural practices and the importance of creating sustainable agricultural and systems for the long-term health of humankind and the biosphere as a whole.

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Contributors

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Hugo Fjelsted Alrøe is a Senior Scientist at the Danish Research Centre for Organic Food and Farming (DARCOF). He holds a graduate degree in horticulture and a PhD in systemic research methodology and ethics from the Royal Veterinary and Agricultural University in Denmark. His main research interests are in the philosophy of science with a focus on cross-disciplinary research, reduction, values and the systemic involvement of science in its subject areas, systems theory, semiotics and ethics and value inquiry in relation to sustainability, precaution, ecological justice and organic agriculture. He has written numerous research articles in these areas and given lectures in many countries. Hugo also works with communication technologies and open source software as tools for research communication and open access. In 2002 he initiated 'Organic Eprints', an open international archive for research in organic agriculture. He is co-editor of the book *Global Development of Organic Agriculture: Challenges and Prospects*, a member of the International Federation of Organic Agriculture Movements task force on rewriting the principles of organic agriculture, and manager of a work package on identifying and integrating values in the European research project 'Organic Revision', which is to support the revision of the EU regulation on organic agriculture.

Paolo Bàrberi is Associate Professor in Agronomy and Weed Science at the Sant'Anna School of Advanced Studies in Pisa, Italy (SSSUP). He completed an MSc in Agricultural Sciences (1989) and a PhD in Environmentally-sound Innovative Crop Management Practices (1994) at the University of Pisa. From 1996 to 2000 he was Assistant Professor in Agronomy and Field Crops at the Department of Crop Production, University of Tuscia, Viterbo, Italy. He lectures in agroecology, weed science, organic farming, and methodology for agricultural research at his own and other universities in Italy. He is one of the coordinators of an International Doctorate in Agrobiodiversity, co-organised by SSSUP, Food and Agriculture Organization of the United Nations (FAO), International Plant Genetic Resources Institute (IPGRI), the Italian

Ministry for Higher Education and the Italian National Academy of Sciences. He has been invited to lecture at the Imperial College at Wye (UK), the Curtin University of Technology (Australia) and the University of Western Australia. Paolo served as the Scientific Secretary of the European Weed Research Society (EWRS) for 2002–05 and has been reappointed until 2009. He has a leading role in orientating the scientific policy of the Society and promoting the activities of EWRS Working Groups. His research activity focuses on weed community dynamics and management in low-external input and organic cropping systems, mainly in arable crops, on the definition of agricultural sustainability indicators, the study of functional biodiversity in agroecosystems, and the optimisation of cropping systems and/or system components (e.g. tillage, fertilisation, pest and weed control) in integrated and organic agriculture. He is the author of more than 100 scientific papers and book chapters and the coordinator of several research and monitoring projects in organic farming at the regional and national level. His research philosophy is to constantly seek a system-based and multidisciplinary approach to agroecosystem study and management.

Kirsten Brandt holds an MSc in Experimental Biology specialising in Cell Biology from the University of Southern Denmark and a PhD in Plant Breeding from The Royal Agricultural and Veterinary University in Denmark. Kirsten has been involved in research and research management since her graduation, mostly at Research Centre Aarslev, Danish Institute of Agricultural Sciences. Since 2004, she has held the position of Senior Lecturer in Food Science at the University of Newcastle upon Tyne in UK. During the first 10 years, the main topic was ornamental breeding and propagation, with a special focus on secondary plant metabolites relative to characteristics such as flower colour and plant resistance. Later, the focus changed to plants as food, in particular the role of plant secondary metabolites in human health and the effect of growing conditions such as organic farming. The topics broadened to a wide range of food quality issues. She has coordinated several major initiatives, including a research program on the cancer-preventing effects of the natural pesticide Falcarinol in carrots and a European Concerted Action on food quality control in organic supply chains, and is establishing a Centre for Food Quality at the University of Newcastle. She is the author of over 120 publications, mostly in the areas of bioactive plant compounds, food quality and *in vitro* plant propagation and breeding. Kirsten has chosen to work at the interface between basic plant physiology and applied sciences such as horticulture or public health, which often means bringing together expertise from different disciplines to ensure that experimental results are applicable. Ultimately, she wants her research to make a real impact on people's lives, in addition to advancing the theoretical understanding of science. Eat more organic carrots!

Tor Arvid Breland is an agronomist, soil microbiologist and agroecologist who does research on the cycling of carbon and nitrogen in ecological and conventional cropping systems. He teaches agroecology and farming systems as Professor at the Norwegian University of Life Sciences in Norway. Breland has extensive publications in soil microbiological processes as important components of resource-efficient and environmentally benign farming and food systems. He is active in design, teaching and administration of the Nordic MSc program in agroecology and in teaching undergraduate courses in ecological agriculture.

Sasha Courville is the Executive Director of the ISEAL Alliance, a network of leading international social and environmental standards and conformity assessment organisations, including the International Federation of Organic Agriculture Movements (IFOAM). This chapter was written while Dr Courville was a research fellow at the Regulatory Institutions Network, Australian National University and teaching Greening of Business at the Asia-Pacific School of

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Nancy Creamer is an Associate Professor in the Department of Horticultural Science and the Director of the Centre for Environmental Farming Systems (CEFS) at North Carolina State University. She received her PhD from Ohio State University in 1994 and has been an academic staff member of North Carolina State University since January 1995. Her areas of specialisation include farming systems research, organic production systems, and cover crop use and management. She is also involved with developing innovative direct marketing approaches for farmers, providing them with a way to capture a higher percentage of the food dollar. The CEFS is an 800 ha facility that focuses on sustainable agriculture research, education and outreach. The CEFS consists of a farming systems research unit, an organic unit, a conservation tillage/cover crop unit, an alternative swine production unit, and pasture-based beef and dairy units. The development of CEFS is a national model for partnership, innovation and interdisciplinary cooperation.

Jennifer Davis completed a BSc (Honours) at the University of Western Australia (UWA) specialising in biological transformations in soil, including decomposition of bioavailable organic matter fractions. After completing Honours with the Soil Biology Group at UWA, she spent a year working on an organic market garden in Perth, WA. Jennifer is completing her PhD in the School of Earth and Geographical Sciences at UWA. Her research centres on the role of soil organisms in sustainable production systems. She is investigating interactions between soil microorganisms and rock dust fertilisers in organic pasture soils using molecular techniques to determine the diversity of the microorganisms involved. Jennifer's interest in organic farming stems from the belief that the incorporation of some organic farming practices into conventional systems may improve their sustainability.

Charles Francis has a BSc from the University of California at Davis in Agronomy with Science Specialisation, and an MSc and PhD from Cornell University in Plant Breeding. He also has an honorary Doctor of Science (Hons Causus) from the College of Agriculture and Forestry, University of Helsinki, Finland. Charles has been a maize breeder, a bean physiologist, and an agronomist and program director in the Small Farm Systems Program of the International Centre for Tropical Agriculture (CIAT) in Cali, Colombia. He was Director of the International Program for Rodale Institute, and Director of the MIAC/Morocco Project in Morocco. Since 1977 he has been Professor of Agronomy and Extension Crops Specialist at the University of Nebraska at Lincoln. In Nebraska he was Director of the Centre for Sustainable Agricultural Systems for ten years. Charles has supervised over 50 students for MSc and PhD degrees. He has consulted widely with USAID, Rockefeller Foundation, CIMMYT, NORFA and various universities. Charles has presented seminars and workshops about sustainable agriculture in 30 countries and in 35 States in the US. Awards include Fellow of his national Agronomy and Crop Science professional societies, International Service in Agronomy, Agricultural Stewardship Award from the Nebraska Sustainable Agriculture Society, and Seventh Generation Research Award from the Centre for Rural Affairs. His research focuses on crop rotations and resource-efficient rural landscape design. Charles teaches about agroecology, urban sprawl, science-based organic farming, sustainable agriculture and international development. He is author or co-author of 115 journal articles, 65 book chapters, and co-editor of six books. He is co-editor of the Nebraska Press series, *Our Sustainable Future*. Charles strongly believes in experiential learning and putting responsibility for learning with students, while he and his teaching colleagues design and catalyse the students' journeys through a complex and dynamic learning landscape.

Nikolai Fuchs undertook an agricultural apprenticeship and agricultural practice in countries such as Australia. He studied agronomy with a focus on nature conservation and landscape ecology in Bonn, Germany, and was head of *Naturschutzentrum Eifel*, Germany, from 1994 to 1997. He was an adviser on *Demeter* farms before becoming Director of the Forschungsring für Biologisch-Dynamische Wirtschaftsweise in Darmstadt, Germany. Since 2001 he has been head of the Agricultural Section at the Goetheanum, Dornach, in Switzerland.

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University of Helsinki, Finland, in 2003 and 2004. In 2005, he became Professor at the University of Applied Sciences in Eberswalde near Berlin, where he teaches animal science in Organic Agriculture and Marketing. In 1994, Bernhard Hörning received the research award for appropriate animal husbandry from the Schweisfurth Foundation in Munich for a study on alternatives in intensive broiler production. Professor Hörning has authored and edited several books and many articles on organic animal husbandry. His research activities focus mainly on alternative housing systems for farm animals, with interests in alternative breeding approaches and organic animal husbandry. He believes that exchange between science and practice is very important in organic agriculture. Consequently, most of his research projects are connected with on-farm research methods, and he gives numerous talks to farmers and has organised conferences to bring farmers, consultants and scientists together. Bernhard is the president of the Society for Organic Animal Husbandry (GÖT) and coordinator for rare pig breeds in the Society for Rare Breeds (GEH), in Germany and other countries.

John Ikerd, Professor Emeritus of Agricultural Economics, holds BSc, MSc and PhD degrees from the University of Missouri, USA. He worked for three years in private industry and 30 years on the faculties of North Carolina State University, Oklahoma State University, University of Georgia and the University of Missouri, before retiring in early 2000. During his academic career, he authored more than 500 publications, including 30 refereed journal articles and chapters in books, even though his primary responsibilities were in extension education. Ikerd served as Head of the Department of Extension Agricultural Economics at the University of Georgia from 1984 to 1988 and as President of Southern Agricultural Economics Association during 1986. He served as a State Liaison for the USDA Sustainable Agriculture Research and Education program during the early 1990s and as State Co-coordinator of Sustainable Agriculture Programs for Missouri from 1995 to 2000. Since retiring, Ikerd spends most of his time writing and speaking on issues related to the sustainability of agriculture, and has also written two books, three chapters in books, and two forewords to books, in addition to more than 100 conference papers.

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Erik Steen Kristensen holds an MScAgr and a PhD from the Royal Veterinary and Agricultural University in Denmark. Erik is Head of the Danish Research Centre for Organic Food and Farming (DARCOF). DARCOF was initiated in 1996 with the main objective to initiate and coordinate research and development for organic food and farming. DARCOF is organised as a 'centre without walls' – researchers remain in their own research environment but collaborate across institutes. The collaboration in DARCOF involves about 150 scientists working in 20 institutes on 42 different research projects. Erik has published research results in over 130 titles, of which about half are published internationally.

Troels Kristensen holds an MScAgr and a PhD from the Agricultural University in Denmark. He works as a Senior Scientist in the Department of Agroecology at the Danish Institute of Agricultural Science. Dr Kristensen has been the project leader and participant in several research and consultancy projects. He is the supervisor of several PhD and Master students in many areas of farming system as well as being the external reviewer for many scientific journals. Troels collaborates in his farming systems research with commercial and private farms on the issue of animal feed. His research also covers different aspects of feed supply on organic and conventional dairy farms with specific emphasis on pasture management, grazing systems and effects of supplemental feeding in animal production. He is an experienced scientist in the design and analysis of on-farm data with respect to production, economy and environment.

Paul Kristiansen has over 15 years experience in the organic movement in Australia and strong links with organic agriculture researchers, extension officers, farmers and industry representatives in Australia and other countries. He has a PhD in Weed Ecology from the University of New England (UNE), having completed a BSc at Monash University and a Graduate Diploma in Horticultural Science at UNE. Paul has held research positions at CSIRO (Macadamia Breeding Program) and the Queensland Department of Natural Resources and Mines (various weed biocontrol projects). He has taught horticulture, soil science, weed management and organic crop protection in both private and public education in Australia for over 10 years, and now works as a Lecturer in Agricultural Systems at the UNE. In addition to supervising several PhD projects on organic farming and sustainable land management, Paul teaches organic agriculture, agricultural systems and viticulture. In his teaching he places a great emphasis in experiential, student-centred learning, believing that 'doing' agriculture is an important part of learning agriculture.

Edith T. Lammerts van Bueren has held a part-time Chair at Wageningen University in the Netherlands as Professor in Organic Plant Breeding since 2005. She is also Senior Scientist and Team Leader of Organic Plant Breeding at the Louis Bolk Institute. The Louis Bolk Institute, founded in 1976, is the only private research institute in the Netherlands specialising in organic farming, and is widely recognised for linking farmers' experiential knowledge and scientific innovation. In 2002, Lammerts van Bueren was awarded a PhD from Wageningen University on the basis of the research and development activities she had conducted at the Louis Bolk Institute over the previous 15 years, together with organic farmers and seed companies. The title of the dissertation was *Organic Plant Breeding: Concepts and Strategies*. Edith is co-founder and president of the European Consortium for Organic Plant Breeding.

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Geir Lieblein has a background in crop sciences and agroecology. He is Associate Professor at the Norwegian University of Life Sciences (UMB). He is involved in education and research that encompasses farming as well as the wider food system. He has been involved in research and teaching in organic agriculture at UMB for the past 25 years. Lieblein is one of the moving forces behind the establishment of a Nordic MSc program in agroecology through UMB and NOVA University that serves students from throughout Europe and the world, as well as those from the region. He has designed curricula for experiential and systems-oriented education. Previously Lieblein worked in Sri Lanka, Tanzania and several European countries.

William Lockeretz holds a BSc from the City College of New York and MA and PhD from Harvard (all in physics). Since 1981 he has been at the Friedman School of Nutrition Science and Policy at Tufts University (Boston, USA), where he is a Professor. For its first 12 years he was editor of the *American Journal of Alternative Agriculture*, which he helped to found in 1986. William is the editor or co-editor of 11 books on agriculture, most recently *Animal Health and Welfare in Organic Agriculture* (CABI, 2004), as well as *Visions of American Agriculture* (Iowa State University Press, 1997) and *Environmentally Sound Agriculture* (Praeger, 1983). He is the senior author of *Agricultural Research Alternatives* (University of Nebraska Press, 1993). From 2000 to 2002 William served on the US Department of Agriculture's National Organic Standards Board, and from 1985 to 1989 on the National Research Council's Committee on the Role of Alternative Farming Methods in Modern Production Agriculture. In 2003 he was elected to the Board of Directors of the International Society of Organic Agriculture Research. William is a Fellow of the American Association for the Advancement of Science, and in 2003 received the 'Spirit of Organic' award from the International Federation of Organic Agriculture Movements.

Stewart Lockie studied agriculture at Hawkesbury Agricultural College before shifting into the social sciences and undertaking a PhD in sociology at Charles Sturt University, Riverina, in Australia. Since 1995 he has been based at Central Queensland University where he is now Associate Professor of Environmental and Rural Sociology and Associate Dean (Research) in the Faculty of Arts, Health and Sciences. Stewart has undertaken numerous research and consultancy projects dealing with agriculture, natural resource management and food for a range of government, industry and community groups. He has written widely on these topics, with recent co-edited publications including *Rurality Bites: the Social and Environmental Transformation of Rural Australia* (Pluto Press), *Consuming Foods, Sustaining Environments* (Australian Academic Press) and *Environment, Society and NaturalRresource Management* (Edward Elgar). While most of his research has been based in Australia, Stewart has held visiting fellowships at the Institute of Philippine Culture in Manila, the University of California, Santa Cruz and the University of Aberdeen, the UK. Stewart also has a strong commitment to the community and environment of the Capricorn Coast in Central Queensland, where he and his family are active members of local permaculture and revegetation groups.

Vonne Lund is a senior researcher at the National Veterinary Institute in Oslo, Norway, working with animal welfare issues. She was previously working at the Swedish University of Agricultural Sciences, from which she has a degree in animal science and a PhD. She also has a degree in teaching from Uppsala University, Sweden. She has been engaged in organic faring since the 1970's and she was one of the first in Scandinavia to work with organic animal husbandry in a university context. For over 10 years she and her family also had a smallholding with sheep, poultry and beef cattle. She has contributed as author or co-author to eight books on organic and animal welfare friendly animal husbandry and has long experience lecturing and leading courses at universities in many countries. Her PhD thesis about ethics and welfare in organic animal husbandry was awarded an international prize. She is an appointed member of the Norwegian National Ethical Committee for Patent Issues, and the Norwegian National Committee for Research Ethics in Science and Technology. Vonne believes it is essential to respect our animal co-workers in agriculture and to provide them good living conditions, and that good welfare for humans as well as animals is a precondition for sustainable systems.

Charles Merfield is completing a PhD on organic carrot seed production at Lincoln University, New Zealand. He initially completed a Higher National Diploma in Commercial Horticulture from Writtle College, UK, and spent seven years managing organic vegetable and herb farms in the UK and NZ. He completed his Masters Degree with Honours, also at Lincoln, on interactions between biological control agents on farmland. He has had extensive involvement in organics, on the practical, political and research levels. He was a founding member of the Canterbury Commercial Organic Growers group, being its chair and secretary for three years. His main area of interest and expertise is in the design of organic vegetable production systems, with a focus on appropriate machinery, especially for weed control including advanced thermal weeding techniques. He is a guest lecturer on organic horticulture at Lincoln University and provides practical consultancy advice to farmers and growers.

Jens Peter Mølgaard received his MSc in horticulture and PhD in agronomy from The Royal Veterinary and Agricultural University, Copenhagen, Denmark. For 12 years he has worked as a scientist at the Danish Institute of Agricultural Sciences, Research Centre Foulum. His prime area of research has been the influence of manure, soil treatment, weeding, crop mixtures and storage on the quality of plant products. He was the manager of several projects on organic potato production concerning tuber quality and potato diseases. In addition, he has been engaged in several projects on organic products and their influence on human health, and is author or co-author of more than 50 papers in scientific journals, magazines and proceedings. He is engaged in the Danish straw-bale building project Friland (www.dr.dk/friland), characterised by mortgage-free building, self-employment and a strong environmental concern.

Ron Morse holds a BSc in Horticulture, a Masters of Science in Plant Nutrition from Utah State University and a PhD in Horticulture from Michigan State University, USA. Ron has seven years of international experience, with long-term appointments in Brazil and Uruguay and short-term consulting assignments in Pakistan, Guatemala and the Caribbean Islands. He has been employed as a Plant Physiologist for Hunt-Wesson Foods and a faculty member in Horticulture at three US universities – Southern Illinois, Pennsylvania State and Virginia Tech. Since 1975, he has served in numerous capacities at Virginia Tech, teaching undergraduate and graduate courses, outreach involvement with grower organisations, and research in sustainable agriculture. He is an internationally recognised expert in sustainable and organic no-till systems for production of vegetable crops. He is the author of over 50 peer reviewed papers and book chapters, and over 60 outreach grower-oriented publications.

David Pearson has a Bachelor of Engineering (Honours) from the University of Technology, Sydney, and a PhD in marketing organic food from the University of New England (UNE) in Australia. David has taught and developed units in strategic marketing and strategic management for undergraduate and Masters of Business Administration students at UNE. His research interests focus on strategic marketing and consumer behaviour for niche products, such as organic food and other agricultural products. Before commencing as a full-time academic, David obtained managerial experience by working at a senior level in both the public and private sectors in Australia. David also has consulting experience which includes the development of marketing and financial feasibility studies, and business plans in many industries for a wide range of clients.

Rhiannon Pyburn graduated from the University of Toronto, Canada, with a BSc in International Development Studies, Resource Management. At Wageningen University in the Netherlands, she obtained an MSc in the Management of Agroecological Knowledge and Socio-technical

Change (MAKS) program. Both her MSc and doctoral research explore social learning among key international social and environmental standard-setting and accreditation organisations on the topic of group certification primarily for small farmers in developing countries within the sustainable agriculture sector, but also in the sustainable fishery, forestry and ornamental marine fish sectors. Fieldwork was undertaken in different countries and production system contexts, including organic and fair trade certified oranges in Brazil, rice in Thailand, mangoes in Burkina Faso, cotton in Uganda, as well as certification options for coffee in Costa Rica. Rhiannon is passionate about organic agriculture, social learning, non-formal education and the plight of small farmers. For several years in between academic degrees, Rhiannon supervised youth programs across rural Canada and Indonesia, facilitating development and environmental education in intercultural contexts. Valuable practical experience in sustainable/organic agriculture was gained through a research internship in Côte D'Ivoire (IDRC-funded) working with village women/youth on traditional agricultural techniques, and through work on organic farms throughout British Colombia, Canada. She has also worked in the Communication Science department at Wageningen University on several contracts related to social learning and beta-gamma (physical/social science) integration. In 2002, she co-edited the book, *Wheelbarrows Full of Frogs – Social Learning in Rural Resource Management*, which captured the Department's varied perspectives on social learning. Rhiannon is now finishing her PhD, continuing consulting work related to group certification and lecturing on (social and organic) regulation and certification.

John Reganold received his MSc in Soil Science from the University of California (UC) at Berkeley and his PhD in Soil Science from the UC Davis. Before joining the faculty in the Department of Crop and Soil Sciences at Washington State University in 1983, John worked with the USDA Natural Resource Conservation Service as a soil scientist and with Utah International Inc., as an environmental engineer responsible for developing reclamation plans for mining operations. As a Regents Professor in soil science, John teaches courses in introductory soil science, organic gardening and farming, and land use and soil management, and conducts research in sustainable agriculture and land use. He also advises undergraduate and postgraduate students in soil science and environmental science. His excellence in teaching and research has been recognised by several awards from Washington State University. John has completed numerous studies measuring the effects of organic and conventional farming systems on soil quality, crop performance, farm profitability, environmental quality, and energy efficiency in the USA, Canada, Australia and New Zealand. He has published more than 100 papers in scientific journals, magazines, and proceedings, such as *Science*, *Nature*, *Proceedings of the National Academy of Sciences USA*, *Scientific American* and *New Scientist*. His studies have garnered national and international attention from newspapers, magazines, radio and television. John has given about 150 invited presentations on organic farming and sustainable agriculture to international and national groups of scientists, farmers, students and consumers from around the world. He has also co-authored a university textbook, *Natural Resource Conservation* (9th edn), and is writing a book on organic and biodynamic wine grape growing.

Stephen Roderick obtained a BSc in Agriculture from the University of Nottingham in 1982 and a Masters degree in Animal Production from the University of Reading in 1988. He has worked as a researcher specialising in sustainable livestock production since 1990, initially at the Kenya Trypanosomiasis Research Institute and then at the Veterinary Epidemiology and Economics Research Institute at Reading University. In 1995 he completed his PhD at Reading on pastoral cattle productivity in East Africa after studying the impact of trypanosomiasis and its control on traditionally managed extensive livestock systems. Stephen has been involved in organic farming research since 1995 and has a particular interest in animal health and welfare. He has co-edited and contributed chapters to a book on this subject. Since 2001 he has been Coordinator of the research and development activities at the Organic Studies Centre, Duchy College, Cornwall, UK.

Lennart Salomonsson is an Associate Professor in Crop Science at the Department of Urban and Rural Development, Rural Development and Agroecology Units at the Swedish University of Agricultural Sciences. His research focus is on interdisciplinary perspectives in Agroecology, with a base in systems ecology theory. He has advised numerous students working on sustainability analysis and systems design of farming systems, which is also the focus of his current research. Salomonsson is also Research Leader for projects that relate to Agroecology and Rural Development. He is a founding member and active teacher in the AGROASIS network in the Nordic Region focused on experiential learning.

Laura Seppänen has an MSc degree in horticulture from the University of Helsinki, Finland. She has worked in research and extension of organic agriculture for 16 years leading, for example, the research project ‘Participatory development of organic vegetable farms’ in Finland. She recently completed her PhD at University of Helsinki, in which she focused on challenges and tools for learning in organic vegetable farming. Laura is working as a research director at the University of Helsinki Ruralia Institute, and is responsible for a multidisciplinary project ‘Local food: impacts and learning challenges’ and is a coordinator of the Finnish part of an EU project. Besides research, Laura teaches organic farming and food systems and supervises students both in agroecology and adult education. Her research is about concepts and boundary crossing in agrofood systems, especially from the point of local and organic food. The other areas of interest include multidisciplinarity in the context of sustainability research and interaction between researchers and practitioners.

Hartmut Spieß studied agronomy in Leipzig, Germany, and thereafter held the position of Head of Animal Production in the Agricultural Production Cooperation. In 1978 he was promoted in the field of biodynamic plant production at the University of Gießen. In 1994, he gained a post-doctoral qualification at the University of Kassel-Witzenhausen in the special area of Ecological Agriculture. Since 1977, he has been the Head of the Department in the Institute for Bio-Dynamic Research, Darmstadt, on the Dottenfelderhof/Bad Vilbel. From 1992 to 1999, he worked in the field of Ecological Plant Protection focusing on research and development. His main areas of focus include chronobiology, efficacy of biodynamic preparations, plant health (especially seed health), fertilisation in ecological agriculture, ecological plant breeding as well as teaching at the Agricultural School Dottenfelderhof in Germany.

Nadarajah Sriskandarajah has a background in animal sciences and systems thinking. He is an Associate Professor at the Unit for Learning at the Royal Veterinary and Agricultural University of Denmark. His work encompasses the design of experiential and systemic curricula for agri-environmental education and research on learning processes in real and virtual classrooms as well as in networks of farmers, citizens, researchers and other stakeholders visioning multifunctional landscapes. He was for a long time attached to the School of Agriculture and Rural Development at the University of Western Sydney, Hawkesbury, in Australia, as an active member of the group leading innovations in agricultural education.

Acram Taji holds a BAgrSc (Honours) from the University of Tehran, Iran, Graduate Diploma in Horticultural Science from the University of Sydney, a PhD in Plant Physiology from

Flinders University, South Australia, and a Certificate in Higher Education from Harvard. Acram has been involved in tertiary teaching in universities in Australia, in the University of the South Pacific in Fiji (and its Tonga and the Solomon Islands centres), the University of Colombo in Sri Lanka, at Osaka Prefecture University in Japan and in the University of California at Davis. She holds the position of Professor of Horticultural Science at the University of New England, Australia. During the 15 years of her professional life Acram has been honoured by national and international research and teaching awards including 'The Lecturer of The Year' in the University of the South Pacific in Fiji, the Japanese Prime Minister Senior Research Fellowship for Foreign Specialists, the prestigious inaugural Australian Award for University Teaching, the Australian Society of Plant Physiologists' prize, the Australian College of Education and New South Wales Minister for Education and Training Quality Teaching Award, the International Association for Plant Tissue Culture and Biotechnology Award and the Flinders University Distinguished Alumnies. She is the author of over 200 research articles and author or editor of eight books mostly in the area of *in vitro* plant breeding, floriculture and horticulture. Acram is passionate about her job and feels privileged and honoured for the opportunity to be a university educator. Her philosophy underpins her teaching. She believes that education is not just about job skills but about teaching people to be good global citizens, is about building cohesive societies and is about caring for the environment and for each other.

Stig Milan Thamsborg holds a MSc and a PhD in Veterinary Science from the Royal Veterinary and Agricultural University, Copenhagen, Denmark. During the first 14 years of his career, besides practicing as a country Veterinarian, Stig was also involved in teaching and research in large animal clinical studies with a strong focus on clinical parasitology and animal health under extensive production conditions, including extensive work in developing countries. From 1997 to 2002 he held an endowed research professorship in Organic Livestock Production and Health during a phase of very rapid expansion of organic farming in Denmark. He holds the position of Professor of Veterinary Parasitology at the Royal Veterinary and Agricultural University in Copenhagen and is the Director of the Danish Centre for Experimental Parasitology. He is the author of over 150 research articles and the author or editor of several books mostly in the area of organic animal health and production, veterinary parasitology and livestock health in general.

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Ariena van Bruggen received an MSc in Plant Pathology from the Agricultural University at Wageningen, the Netherlands, and a PhD degree in the same area from Cornell University, New York, USA. She specialised in diseases of vegetable crops, and after a brief post-doc in Ithaca, she took a position as Assistant Professor in diseases of vegetable crops at the University of California (UC) at Davis. She moved from Assistant to Associate and full Professor of Plant Pathology at UC Davis, but after working for 13 years in California, van Bruggen returned to her native country. She holds the Chair of the Biological Farming Systems Group at Wageningen University. Within plant pathology, she focused mostly on soilborne diseases, and received two international awards for research on a disease of lettuce caused by a new bacterial species. She also compared root diseases and microbial communities in organic and conventional crops. Her research ranges from microbial to landscape ecology in organic farming systems. She is the author of over 100 research articles and co-author or editor of eight books in the areas of plant pathology, sustainable agriculture and food production chains. For many years, van Bruggen taught the courses 'diagnosis of field and vegetable crop diseases' and 'cultural and biological diversity' at UC Davis. She now teaches various courses on organic agriculture. She is one of the coordinators of the European Network of Organic Agriculture University Teachers. Van Bruggen loves teaching, especially interacting with organic agriculture students who are generally exceptionally motivated and dedicated.

Kees van Veluw has an MSc in Agriculture and is a consultant in the project Stimulating Organic Farming in the Gelderse Vallei region of the Netherlands. Kees has worked in the Netherlands as Coordinator of an MSc program in Ecological Agriculture at the Wageningen University. He wrote a book in Dutch on biological animal husbandry. In Africa he worked for seven years as an Agricultural Extensionist in a community-based development project implemented by UNICEF and was Head of the Department of Agricultural Economy and Extension of the University for Development Studies, Tamale, Northern Ghana. His experience is in guiding the conversion process of farmers, trainers and policy makers towards organic farming.

Henk Verhoog studied biology at the University of Amsterdam in the Netherlands. From 1968 until 1999, Henk was an Associate of the Institute of Theoretical Biology of Leiden University, lecturing on the social and ethical aspects of biology where in 1980, he submitted his Doctor of Philosophy dissertation on the topic of 'Science and the social responsibility of natural scientists'. His research interests and publications are mainly in the field of the relationship between science and ethics, and the philosophical aspects of the human–animal (human–nature) relationship. He was a member of state advisory boards on the ethics of animal experimentation until 1993, the genetic modification of animals until 1999 and, the release of genetically modified organisms (GMOs) in the environment until 2006. From October 1999 onwards, he has worked as an associate of the Louis Bolk Institute in Driebergen, an independent research centre in the field of organic agriculture, nutrition and health care as related to organic agriculture.

Peter von Fragstein und Niemsdorff holds a Diploma in Agricultural Biology and a PhD from the University of Hohenheim, Germany. After the completion of his PhD he worked in the Institute of Fruit, Vegetable Science and Viticulture at the University of Hohenheim. He received his Habilitation from the Faculty of Agriculture, International Rural Development and Environmental Protection at the University of Kassel, Germany. He was appointed to a Personal Chair in Organic Vegetable Production in 2001 at the University of Kassel. His research and teaching centre around nutrient management in ecological agriculture, crop rotation and design, and ecological vegetable growing. Professor von Fragstein und Niemsdorff is a leading organic agriculture scientist in Germany and internationally recognised for his passionate views on this area of research.

Arjen Wals is an Associate Professor within the Education and Competence Studies Group of the Wageningen University in the Netherlands. He specialises in the areas of environmental education, participation, communication and interactive policy making. His PhD, obtained from the University of Michigan in Ann Arbor, USA, under the guidance of UNESCO's first Director for Environmental Education, the late Professor William B. Stapp, explored the cross-roads between environmental education and environmental psychology. More recent research topics include: making biodiversity and sustainability meaningful through education, the role of conflict in environmental and social change, sustainability in higher education, education and training for integrated rural development and the development of critical consumerism. He is the (co)author of over 120 publications on environmental education related issues and serves on the editorial board of four environmental education research journals. He is the Past President of Caretakers of the Environment International and of the Special Interest Group on Ecological and Environmental Education of the American Educational Research Association (AERA).

Christine Watson holds a BSc (Honours) degree in Soil Science from the University of Reading and a PhD in farming systems analysis from the University of Aberdeen. She holds the position of Reader in Organic Farming Systems at the Scottish Agricultural College (SAC), and has been involved in research in organic farming since the mid-1980s. She is particularly interested in nutrient cycling and has conducted research at a range of scales from soil–plant–microbial interactions to whole farm systems. Christine is a member of the management team for the Postgraduate Diploma/Master of Science degree in Organic Farming at SAC. She is also a member of the UK Advisory Committee on Organic Standards. Christine was involved in founding the UK Colloquium of Organic Researchers and is also involved in running the soil fertility section of the International Society of Organic Agriculture Research.

Martin Riis Weisbjerg holds degrees of MSc and PhD in animal science and ruminant nutrition from The Royal Veterinary and Agricultural University, Denmark. After a short period of work in the extension services Martin joined the staff of Research Centre Foulum, Danish Institute of Agricultural Sciences, where he now holds the position of the Senior Scientist. His main research area is ruminant nutrition, with focus on digestive processes and feed evaluation. Martin has also participated in many other projects, which have provided him with a broad experience in ruminant nutrition and animal production. He has participated in several research projects funded by the Danish government in Zimbabwe, Tanzania, Uganda, Malawi and Namibia in cooperation with universities and research institutes in these countries. Martin is the author of research articles and book chapters in the area of ruminant nutrition. He has taught undergraduate courses and has supervised MSc and PhD students in The Royal Veterinary and Agricultural University in Denmark and at University of Zimbabwe and University of Namibia and has been external examiner for MSc and PhD theses at European and African universities.

Andrew White has worked in the Australian rangelands since 1977. Spending considerable time in the Northern Territory, Queensland and South Australia, he has worked principally as a researcher or extension officer, and more recently as the Executive Officer for a regional Natural Resource Management Group. Andrew holds a BSc from The University of Adelaide, South Australia, a Graduate Diploma in Natural Resource Management from Roseworthy Agricultural College, South Australia and a Masters Degree in Rangeland Management from the University of New South Wales. His knowledge of the Australian rangelands is extensive, having worked in the chenopod shrublands of South Australia, the acacia woodlands of central Australia, the Channel Country and Mitchell grass plains of Queensland and most recently in the tropical savannas in the Northern Territory. His work has mostly focused on the vegetation dynamics of the various regions and management of the plant–animal interface to enhance sustainable production systems. He has had extensive dealings with members of the organic OBE Beef group while working on a research project investigating sustainable grazing practices in the Channel Country of south-west Queensland and north-east South Australia. Andrew is undertaking a PhD with CSIRO and the University of Queensland at the Pigeon Hole Project, researching sustainable and profitable grazing management systems for the northern Australian pastoral industry. The Australian rangeland environment and the current land uses and management practices provide opportunities for genuinely sustainable uses with little need for external inputs. Andrew is delighted to be involved with researching, developing and promoting these land uses.

Els Wynen has a BSc in Tropical Agriculture from Deventer (the Netherlands), an MSc in Agricultural Economics from Reading University (UK) and a PhD in Agricultural Economics at La Trobe University (Melbourne), focusing on the economics of organic agriculture, particularly the cereal–livestock industry in Australia. As a founding member of the National Association for Sustainable Agriculture, Australia, Els was the publicity officer and policy adviser, later becoming the overseas marketing officer until early 1990s. Before specialising in organic agriculture, Els worked as an agronomist with the Food and Agricultural Organization of the United Nations (FAO) in Lesotho, as an agricultural economist with the Economic and Social Commission of Asia and the Pacific in Thailand and with the then Bureau of Agricultural Economics in Canberra. Els has since made considerable contributions to organic agriculture. Following the establishment of the Eco Landuse Systems consultancy, Els worked on organic product marketing, organic standards and certification, conversion to broadacre organic farming, large-scale change from conventional to organic cereal–livestock farming, and has produced reports regarding the biodynamic dairy industry, organic and conventional cereal–livestock farming, and research levies and expenditure in Australia. She has also worked extensively in countries such as Denmark and the UK examining the effects of conversion to organic agriculture, and effects of policies on conversion to organic agriculture in some European countries and Bangladesh. For the UN's FAO Els has produced three reports relating organic agriculture to food security, research priorities and the certified organic market. Her most recent work was for the UN Conference on Trade and Development in Geneva, for which she edited a book on organic agriculture and developing countries, and worked on world harmonisation/equivalence of organic standards and certification.

Chapter 1

Overview of organic agriculture

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> The most important factor that will enable organic agriculture to usefully contribute to food security is the attitude of decision-makers. Organic agriculture must be discussed with an open mind, with the advantages and disadvantages being clearly considered. (Wynen 1998)

The search for sustainability

The acquisition of food, textiles and other resources from plants and animals has been a major concern for human societies, from the earliest days as hunter-gathers, through pastoral and swidden phases, to agrarian societies, with an associated trend away from nomadic to sedentary lifestyles. Yet as agricultural production intensified and expanded, the negative effects on the underlying resource base have also increased. The history of environmental damage caused by agriculture is well documented; impacts include air pollution from greenhouse gases such as carbon dioxide, methane, nitrous oxide; land degradation as a result of clearing, cultivation of sloping land and salinity; water pollution from fertilisers, pesticides, overuse and wetland draining; and the loss of biological and ecological diversity (Norse and Tschirley 2003). In the area of conventional weed science, for example, considerable attention has been placed on herbicides but this has not achieved a long-term decline in agricultural weed populations. Instead, farmers have become dependant on herbicides as widespread resistance in a range of weed species has emerged (Gill 2002).

Although the extent of the damage may be disputed by some, the seriousness of these agricultural sustainability issues is reflected in the formal policies implemented in many countries to reduce those impacts, and in the financial benefits available for (verified) good environmental performance (OECD 2001). Policies designed to improve the environmental sustainability of agriculture include bans on increasing numbers of pesticides such as the fumigant methyl bromide, financial incentives to revegetate, penalties for water pollution and funding for research into efficiency improvement (e.g. fertiliser applications) or damage abatement technologies. The various policy tools may be applied in an *ad hoc* way or, preferably, in a strategic manner that integrates the tools and creates a supportive milieu for adoption and improvement. In regard to measuring performance, environmental management systems (EMS) for agriculture have recently become popular with some farmers, government agencies and consumers. EMS are relatively new and suffer from several limitations including credibility, complexity, financial risk, uncertain consumer demand and patchy evidence of environmental improvement (Chang and Kristiansen 2006).

Is organic agriculture the answer to the sustainability problem?

To ensure that organic agriculture is the answer to the sustainability problem, it has to be adapted to the local farming, social, geographical and climatic factors. The European form of organic agriculture, especially its current market-driven style, is not necessarily the most appropriate system for other countries. The principles of organic agriculture are guides to tailor organic practices to each individual farming location. For example, there will always be locations where certain crops cannot be grown sustainably or economically using the current range of organic methods. As more becomes known about the environmental, social and economic performance of organic agriculture in a growing range of settings (OECD 2003), rational decisions can be made about the prospects and limitations of organic agriculture and general requirements for success can be identified.

It could be expected that settings similar to that found in Europe where organic agriculture was originally developed would be the most suitable. However, low-input systems in remote locations with marginal environments (e.g. rangeland grazing) have also been found to be well suited to organic agriculture. In New Zealand and particularly Australia, the farming conditions faced by the early proto-organic growers were very different from those encountered in Europe. In Australia the unreliable and sparse rainfall, ancient depleted soils, widely dispersed production bases and very small consumption bases present serious challenges for agriculture, both organic and conventional. Some adaptation and experimentation was going to be necessary. In parts of south-eastern Australia broadacre, organic cropping depletes phosphorus from the soil because the allowable organic fertilisers are inadequate. In contrast, further north in the rangelands of western Queensland, running beef cattle organically is straightforward and the farms appear to be no less sustainable than before conversion. Clearly, the sustainability question must be addressed in terms of particular farm types.

In many countries, organic agriculture has affected most areas of agriculture and food production, often starting in niche markets such as ‘direct to customer’ or on-farm processing. It has been adapted to local conditions, both social and agronomic, to produce viable sustainable farming strategies. This has resulted in a multitude of sustainable and profitable organic enterprises emerging around the world (Stokstad 2002, Thompson 2002) showing that organic agriculture can have a central role in ensuring that agriculture becomes fully sustainable.

Organic agriculture is just a small part of the agribusiness world, which itself is just a small part of the wider global socioeconomic system and its dominant cultural values. Consequently, the capacity of organic agriculture to influence, for example, international trade, labour relations and agrichemical policy is limited. An example of this lack of power is in the US National Organic Program (NOP) deliberations, in which representatives from the organic movement were secondary to government agencies (Merrigan 2003). Although the movement may internally aim for certain ideals, its development is inevitably shaped by global markets and politics. Stepping back from looking at the organic movement’s success, it is apparent that despite the enormous growth since the 1990s, organic agriculture still only makes up a tiny proportion of all commercial agricultural production (Norse and Tschirley 2003).

This introductory chapter presents an overview of the history and development of the organic movement from its roots in early 1900s Europe to its current position as a high-profile, thriving niche sector in global agriculture. The chapter describes some of the key people and trends which shaped modern organic agriculture and reports on the status of organic agriculture around the world in specific countries. In order to understand the aims and practices of organic agriculture, the evolution of the core principles are also discussed. Finally, some of the challenges for organic agriculture are identified.

Definition of organic agriculture

Organics, or the 'O-word' as Mark Lipson (1997) has wryly called organic agriculture in recognition of the ambiguous nature of the word, is a problematic label that can be interpreted to mean a wide range of things. The term 'organic' was first used in relation to farming by Northbourne (1940) in the book *Look to the Land*: 'the farm itself must have a biological completeness; it must be a living entity, it must be a unit which has within itself a balanced organic life'. Clearly, Northbourne was not simply referring to organic inputs such as compost, but rather to the concept of managing a farm as an integrated, whole system (Lotter 2003).

The use of 'organic' in reference to agricultural production and food is legally constrained in many countries, and some certification agencies have more stringent compliance requirements than others. Many farmers in less developed countries may practice organic agriculture by default based on their traditional methods of production. However, it is useful to provide a general definition of organic agriculture to indicate briefly what the production systems are designed to achieve.

The international food standards, Codex Alimentarius, state:

> Organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasises the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system. (FAO 1999).

The term 'organic agriculture' as used here is based on the Codex definition just given. However, the term is expanded to include the full organic and biodynamic supply chain from inputs to final manufactured goods, as well as cultural and social aspects of the movement, not just the on-farm production aspects. The phrase 'organic movement' may be no longer applicable and that the appropriate term is 'organic industry' (Cornish and Stewart 2002). However, the continued existence of a major social and political role for organic agriculture suggests that it is more than just an industry. Conservation farming (reduced tillage) also continues to be a social movement (e.g. WANTFA 2004) even after an industry has been created in the commercial arena.

Organic standards are not static, with revisions of certification standards commonly occurring every few years. Certification agencies usually have some form of certification review committee that considers new materials that become available for use, new information about existing allowed inputs, or new production and processing techniques that are introduced.

The commonly used term 'conventional agriculture' refers to the standard, dominant farming approaches promoted and researched by most government and agribusiness groups and practiced by farmers and growers throughout the world. Usually, conventional agriculture imposes no restrictions on management other than those required by law. To some extent, organic and conventional agriculture define each other. Organic agriculture could not exist as a concept until an alternative agricultural paradigm came into being allowing a distinction to be made. Indeed, the term 'organic' only became dominant from the 1960s onwards. It is acknowledged that the term 'conventional' masks the great diversity of management strategies used; for example, a conventional grain grower may use mineral fertilisers but also use green manures and avoid pesticides, or a permaculture orchardist may choose to use herbicides to control woody weeds in sloping land. The growing adoption of EMS indicates the recognition from various points along the supply chain of the need for improved monitoring of agricultural impacts (Carruthers and Tinning 2003).

The origins of organic agriculture

Early development

The origins of modern organic agriculture are intertwined with the birth of today's 'industrially based' agriculture. Many of the practices of organic agriculture were the only option for farmers before the advent of chemically synthesised fertilisers, biocides, medicines, mechanisation and fossil fuels that allow industrial agriculture to function. Without recourse to such technologies, farmers had no option but to work within biological and ecological systems. For example, the only source of fertiliser to replace nutrients from cropped fields was human and animal manure and leguminous plants. Failing to rotate crops caused a build up of pests, as there were no pesticides to control them. From this perspective, organic agriculture is the original and mainstream agriculture and 'conventional' industrial agriculture is the one that departs from the practices that agriculture has been following since its inception.

This split between industrial and organic agriculture dates back to the start of the 19th century when it was discovered that it was the mineral salts contained in humus and manure that plants absorbed, and not organic matter. Sir Humphrey Davy and Justus von Liebig were the key founders of this theory and published their ideas in *Elements of Agricultural Chemistry* (Davy 1813) and *Organic Chemistry in its Application to Agriculture and Physiology* (von Liebig 1840). Their argument was that inorganic mineral fertilisers could replace manures and bring agriculture into the scientific fold, with resulting increases in production and efficiency. The agricultural revolution began in the 1840s and with it came the first commercial production of inorganic fertilisers. However, like many revolutions, it was not without mistakes and significant uptake of fertilisers did not occur until the start of World War Two (Grigg 1989).

It was in the 1920s that individuals who were concerned about the direction agriculture was heading first started to speak out and to join together. Rudolph Steiner, the founder of the philosophy of 'Anthroposophy' gave his agricultural lectures in 1924. Although these lectures and other Steiner teachings were the foundation of biodynamic agriculture, which differs from organic agriculture principally as it has spiritual, mystical and astrological aspects, they were prophetic in their criticism of industrial agriculture and in plotting an alternative course. The first organic certification and labelling system, 'Demeter', was created in 1924 because of Steiner's actions (Rundgren 2002).

During this time, Robert McCarrison, a distinguished scientist, was researching the vitality of the fighting men of India and why they lacked diseases common in the west. He promoted health as a positive concept of vitality rather than a negative form viewed as an absence of disease. Good health was based on a diet of wholesome food – mostly fresh plants and grains with modest amounts of meat, grown on land to which all manures were returned (i.e. following the 'law of return'). McCarrison followed up his observations with dietary experiments on rats, feeding one group on the diet of the Indians and the other of the British poor. The rats on the Indian diet flourished, while the others suffered a range of diseases and negative sociological effects. This led McCarrison to expound the importance of a wholesome diet grown on soil fertilised with manures and other organic matter.

Sir Albert Howard was also working in India in the 1920s on an experimental agricultural research institute he established. Howard was a highly capable scientist as well, and while his training was more than sufficient to understand the new chemical ideas, his upbringing on a Shropshire farm made him highly sceptical of the approach. He was a keen observer of the local peasant farmers and said that he learnt far more from them than from his scientific training. Howard undertook a wide range of activities including a highly successful plant breeding program and observed the effects of how forage was grown on the health of farm animals. This led him to believe in the inextricable linkages between the health of the soil and the health of the plants and animals fed by that soil. This lead to him adapting oriental methods of composting to Indian conditions which resulted in the 'Indore process' of composting which is now inextricably linked to his name. These experiences were distilled into his book *The Waste Products of Agriculture* (Howard 1931), which spread his message across many continents.

Beyond Europe: further evolution and new alliances

It was the work and publications of people such as Howard, McCarrison and Steiner that influenced the next wave of organic pioneers. This second wave brought the organic movement into being, with the establishment of the early associations such as the Rodale Institute in the United States of America (USA), Soil and Health in New Zealand and the Soil Association in the United Kingdom (UK). The term 'organic' was first used in relation to farming by Northbourne (1940) (see above).

In the UK, Lady Eve Balfour was setting up the 'Haughley experiment', which compared organic and non-organic production over the long term. She also wrote the highly influential *The Living Soil* (Balfour 1943), which was partly informed by the Haughley experiment. She was also the first president and founding member of the Soil Association in 1946. Pre-dating both of these organisations was the Soil and Health Association in New Zealand, founded in 1942 by Dr Guy Chapman, a practicing dentist, originally under the name of the 'Humic Compost Club'.

In Switzerland, Hans and Maria Mueller were pioneering organic farming techniques. Herr Mueller was encouraged by the biodynamic agriculture of Steiner and developed the 'organic–biological' farming method in the 1950s. Hans-Peter Rusch, a medical doctor, microbiologist and good friend of Hans provided the scientific basis for Hans's work in his book *Bodenfruchtbarkeit* [Soil Fertility] that linked soil microbiology with fertility (Rusch 1964). This movement became more formalised in the 1970s with the adoption of the trade mark Bioland, now the largest certifier in Germany (Haccius and Lünzer 2000).

In the late 1930s in rural Pennsylvania, USA, J.I. Rodale was keen to learn about and practice organic agriculture. He quickly came to realise the importance of restoring and protecting the natural health of the soil to preserve and improve human health. In 1947 he founded the Soil and Health Foundation that later become The Rodale Institute. He was also responsible for a wide range of publications on health and farming and gardening organically, with a central message and philosophy of 'healthy soil, equals healthy food, equals healthy people'.

Independent developments were occurring in Japan. In 1936, Mokichi Okada began practicing 'nature farming'. Nature farming includes spiritual and well as agronomic aspects with a view to improving humanity. It therefore has strong similarities to the biodynamic agriculture and anthroposophy of Rudolph Steiner. The Sekai Kyusei Kyo organisation was formed and continues to promote 'Kyusei nature farming' with experimental farms and offices located throughout South-East Asia. An offshoot group, the Mokichi Okada Association formed in 1980 with the aim of demonstrating the scientific validity of their farming methods (Setboonsarng and Gilman 1999). At about the same time as Okada was establishing his movement, Masanobu Fukuoka began a different approach to natural farming in Japan. With a background in microbiology and soil science, Fukuoka aimed to practice a simple form of agriculture, sometimes known as 'do nothing farming' (Setboonsarng and Gilman 1999). Like Okada, Fukuoka's farming approach also had a spiritual underpinning (Fukuoka 1978). The continuation and spread of these movements highlights the importance of seeing organic agriculture as a global phenomenon, not simply a European one.

While many of these organic pioneers' ideas are still relevant to modern organic agriculture, there were a considerable number of pioneers whose political and religious views would be anathema to today's environmentally minded, socially concerned, politically left-of-centre, organic supporters. Many organic pioneers were significantly to the right of the political spectrum and strongly Christian, to the point of fundamentalism and evangelicalism. The politics, philosophy and religious motivations of these organic forerunners in the UK have been well documented by Conford (2001). The reason why the ideas of some organic pioneers are now foreign to the modern organic movement is that it underwent significant change and upheaval in the 1960s. The publication of *Silent Spring* by Rachel Carson (1962) was a key turning point for, and the start of, both the modern organic and environmental movements. This change could well be considered a revolution and, at the least, a significant evolution of the organic movement. Indeed, many of the concerns and concepts of environmentalism and modern organic agriculture would be quite alien to many of the organic pioneers, just as the politics and religion of some pioneers are alien to most involved with the modern organic movement. A case could be argued that environmentalism saved the organic movement from obscurity as it had lost the post World War Two argument over the direction of agriculture and was in significant decline through the 1950s. So while there is a continuum of thought and membership from the earliest days to the present, the modern organic movement is radically different from its original forms. It now has environmental sustainability at its core in addition to the founders concerns for healthy soil, healthy food and healthy people.

Silent Spring opened the world's eyes to the damage that pesticides and other toxins were doing to the global environment. As such, *Silent Spring* brought a whole new raft of arguments against industrial farming in addition to those that the organic movement had been pushing for many decades.

The 1960s, in which *Silent Spring* was published, were also a time of significant social change and upheaval. New modes of political and philosophical thought were emerging and being hotly debated. Many of these were also highly influential within the changing organic movement. Examples of these ideas include *Limits to Growth* (Meadows *et al.* 1972) that considered the issue of the growth of the human population and the global economy and asked questions such as: what will happen if growth in the world's population continues unchecked? What will be the environmental consequences if economic growth continues at its current pace? What can be done to ensure a human economy that provides sufficiently for all and that fits within the physical limits of the Earth? Another was E.F. Schumacher's *Small is Beautiful: A Study of Economics as if People Mattered* (1974) with its many radical ideas, including the concept of sacrificing economic growth for a more fulfilling working life and making quality of life the central goal of economics. Schumacher was also a president of The Soil Association.

In the 1970s, organic agriculture re-emerged as an ecoagriculture and the strengthening of existing organic organisations and the founding of new ones occurred, many of which were focused on the process of certification of farmers and growers. Although there was growing interest in organic agriculture, it was still clearly outside of mainstream agriculture and national politics, and while members of the movement worked tirelessly, they gained little traction with authorities. The levels of self organisation, however, were increasing rapidly, from individual groups working alone to increasingly coordinated action.

The formation of a formal global network is one of the landmarks by which social and political movements can say they have come of age. For the organic movement this was the founding of the International Federation of Organic Agriculture Movements (IFOAM) in 1972, which to this day, remains the only global organic non-governmental organisation (NGO). Its creation and continuation was no easy task. Like many other organic organisations in its earlier years, it depended heavily on vast amounts of goodwill, the hard work of mostly unpaid people and its financial security was often in the balance. It has grown from a body that national governments ignored or argued against, to one that now commands the respect of governments and intergovernmental organisations. IFOAM's mission is 'leading, uniting and assisting the organic movement in its *full diversity*' [emphasis added] (Woodward and Vogtmann 2004, IFOAM 2005). The main aims of the organisation are to:

- provide authoritative information about organic agriculture, promote its worldwide application and exchange knowledge;
- represent the organic movement at international policy making forums;
- make an agreed international guarantee of organic quality a reality;
- maintain the Organic Guarantee System, setting international organic standards and certification procedures and auditing member certification organisations to these standards; and
- build a common agenda for all stakeholders in the organic sector.

Explosive growth in organic agriculture occurred in the 1980s. The reasons for this are numerous and many were outside the control of the movement. The intensification of agriculture had become a national political issue, fuelled by public concerns such as the increasing destruction of valued features of the farmed landscape, the intensification of livestock production (e.g. battery hens) and food scares (e.g. bacterial contamination) which resulted in the public first discovering how industrial food production and processing systems worked, many of which they found shocking and repugnant. Organic food offered an alternative, resulting in considerable increases in organic food consumption during food scares. Increasing wealth and disposable income in some developed countries resulted in organic food becoming highly 'fashionable' among higher socioeconomic groups. This is highly ironic, as the purchasing and consumption of organic food as a symbol of social status is an anathema to the philosophy and principles of organic agriculture (Guthman 2000).

Organic agriculture goes global

Beyond the industrialised countries of western Europe and North America, a large growth in organic agriculture was occurring during the 1980s in parts of Oceania, Central and South America, Asia and Africa. Many of these regions had existing indigenous farming systems that could be readily adapted to organic agriculture, the export earnings were valuable, labour was available, and some places received support from, for example, their governments, aid agencies and NGOs. Although there are many local and regional movements around the world that are similar to (or compatible with) organic agriculture, it is the latter which has become the most well known and widely adopted complementary farming system. The other systems show how different societies develop their own approaches to low-external-input or non-chemical farming depending on their world view and the natural, intellectual and economic resources available to them. These indigenous systems themselves have enormous value in their own right (Peroni and Hanazaki 2002) and, where appropriate, should be maintained and supported. However, where the choices for farmers are changing, becoming more market orientated, for example, then a hybrid of local farming methods and organic agriculture may offer a viable alternative. Some of the incentives and constraints for farmers adopting organic agriculture in less developed countries are listed in Table 1.1.

The traditional farming systems of Central and South America have been well studied over many years (Gliessman 1985) and the principles and practices observed in these systems have been used to develop the concept and practice of 'agroecology', a scientific approach to low-input farming (Vandermeer *et al.* 1998). The emphasis on enabling biological and ecological processes, using existing resources and trading locally in the local farming system is well suited to organic agriculture. There has been a high level of adoption of organic agriculture in Central and South America in terms of certified land area and number of farms, with Argentina having

Table 1.1 Incentives and constraints for farmers adopting organic agriculture in less developed countries (after Parrott and Marsden 2002 and Walaga 2000)

Incentives	**Constraints**
Disillusion with Green Revolution technologies	Lack of knowledge about organic agriculture
The inaccessibility or high cost of Green Revolution technologies	Lack of economic and political advocacy
Organic agriculture valorises indigenous knowledge	Population pressures encourage intensification
The influence of the environmental and development movements	The high cost of certification by foreign organisations
Premiums and market opportunities	Low literacy levels in rural areas make record-keeping a problem
	Lack of trade liberalisation in some countries prevents development of exports

the second highest amount of land under organic production in the world and Mexico having the greatest number of farms. With a large agricultural base, diverse environments, good labour supplies and close proximity to North America, many organic growers in Central and South America have been successful, principally in the export markets. However, socioeconomic constraints such as poverty and land tenure have shaped the process of adoption and adaptation of organic agriculture (Parrott and Marsden 2002).

Although Argentina has 3 million hectares of land under organic production (Yussefi 2004), 74% of that land is owned by 5% of the organic farmers (Lernoud and Piovano 2004). Remove those few large farms and the area of organic land would rank a more modest sixth globally, between Brazil and Uruguay. Beginning in the 1980s, the Argentinian organic movement has developed strong formal certification processes, good export links and has received valuable government support. In a show of diversity, Argentina has also eagerly adopted genetically modified crops, having the world's second largest area of such crops after the USA, with 10 million hectares grown in 2000 (Coffman 2001) and 14.2 million hectares in 2003 (Human Genome Project Information 2004). Like Argentina, Mexico exports most of its organic produce, 70% of which is coffee (Tovar and Cruz 2004). Smallholders make up about 98% of the 28,000 certified organic growers in Mexico, plus a small number of large *fincas* (estates) growing crops such as cocoa, sugar and coffee. Apart from an early biodynamic pioneer producing certified coffee in 1967, organic agriculture began to emerge in the 1980s and 1990s with the aid of some government support and easy access to US markets. However, Mexican organic producers still rely on overseas certifying agencies for exporting their goods and suffer from a lack of state support for research and development, a poorly developed domestic market, as well the dependence on foreign companies for marketing. In Cuba, the collapse of the Soviet regime in the early 1990s caused subsidies for conventional farm inputs to cease and the main markets to disappear, forcing the nation to seek sources of raw materials and alternative markets (Kilcher 2001). In response, Cuba developed several programs to promote organic agriculture including rearing biological control agents, producing bulk compost, restructuring state farms and developing training and certification frameworks. Although the country has not entirely moved away from intensive, export-oriented conventional agriculture based on plantations, Cuba produces 65% of its rice and 50% of its fresh vegetables organically.

Several recognised complementary agricultural systems have also been developed in Asia (Setboonsarng and Gilman 1999). During the Later Vedic Period (1,000 BCE–600 BCE) in India, a series of three works codified a system of agricultural principles and practices in great detail. This indigenous knowledge is still applied today in parts of India and acts as an aid for farmers converting to organic agriculture (Mahale and Sorée 2002). Two very worthwhile aspects of integrated farming that were traditionally overlooked by the organic movement are aquaculture and mariculture. Yet in Asia some ecological farmers have extensive knowledge about these subjects that can be readily integrated with organic agriculture methods. Despite a long history of sustainable agricultural production in China, modernisation of farming practices during the 20th century led to the abandonment of customary methods and knowledge. This trend changed during the 1980s when China began carrying out a research and demonstration program for ecological agriculture. By 1990, they had entered the international organic market with tea certified by a foreign agency, in 1994 the Organic Food Development Center was established and the following year a set of national organic standards was published (Zong 2002). China is unusual because the introduction of organic agriculture has been a top-down process (Zong 2002), unlike the experience of most countries where organic agriculture has been a farmer/consumer-based movement, initially championed from the bottom up. The other example, Cuba, is also a socialist state.

Many parts of Africa experience severe poverty and face some of the most difficult conditions for agricultural production. Developing solutions is an ongoing problem, and it is likely that many strategies will be needed, each customised to the needs of the targeted community. Organic agriculture has been adopted in few African countries. For example, the establishment of the Kenyan Institute of Organic Farming in 1987 increased the transfer of information about organic methods and, although the government was not initially supportive, the country now has the largest number of IFOAM members of any African nation (Parrott and Marsden 2002). Countries in the west of Africa such as Senegal and Burkina Faso have also established NGOs that set local certification standards to reduce external certification costs, provide training in organic food processing, labelling, packaging and storage and establish local and distant markets for selling organic produce (Anobah 2000).

Australia has the largest (10 million hectares) and Argentina the second largest (3 million hectares) area of organic farmland in the world (Yussefi 2004). A major portion of the organic land in these countries is used for extensive, low-input grazing on relatively few individual farms. The high level of adoption of organic agriculture by graziers in these countries suggests that organic pastoral production was technically easier to implement than organic broadacre cropping. Both countries have well-developed export markets for organic grains (Halpin and Brueckner 2004, Lernoud and Piovano 2004), so differences in market size and accessibility are unlikely to be a limiting factor for organic cropping.

The modern organic movement

Scientists became increasingly interested and aware of organic agriculture in the 1980s, even those who were not supportive of alternative agricultural systems. They found the academic climate and funding sources were more amenable to its study than in previous decades, which resulted in a rash of research, much of which, unfortunately, was comparisons of organic and non-organic agriculture, rather than research designed to assist organic producers or underpin organic principles and practices (Lockeretz 2002). By the end of the decade, the level of interest in organic agriculture and the volume of information compiled about organic methods had become sufficient to enable the highly successful publication of the landmark book *Organic Farming* by Nicolas Lampkin (1990).

Trends that began in the 1970s, and accelerated through the 1980s, continued to flourish during the 1990s and into the new millennium. Demand and production continued to grow exponentially around the world, often at 20–30% per year. Formal political and legislative recognition was achieved. Normally this was started by bringing organic agriculture under legislative control. Following this were intergovernmental agreements to facilitate international organic trade, mostly by creating systems by which certification standards in the exporting country were shown to be equivalent to those of the importing country, a system that parallels and duplicates IFOAM's Organic Guarantee System. Significant political traction was also being made in international/intergovernmental agencies such as the European Union (EU) and the United Nations Food and Agriculture Organization. Public concerns about food and its production systems continued with further 'food scares' such as bovine spongiform encephalopathy (BSE) in the UK and the emergence into public awareness of 'genetic engineering'that in parts of Asia, Australasia and particularly Europe became a highly charged political issue.

Science increasingly became a tool to demonstrate the benefits of organic agriculture and the problems with industrial agriculture (Pretty *et al.* 2000). This helped organic organisations make the case for much closer cooperation between themselves and other environmentally aligned organisations, for example nature conservation groups. It also showed that useful research could be carried out on organic farms. Since the 1980s, numerous organic research centres and associations have been established internationally; taken active roles in conducting new research in the agronomic, environmental and social sciences; have documented and published findings to fill the strong demand for information; and provided extension and training to farmers and advisers. Several NGOs and companies began to perform an auxiliary function to the certifying agencies by carrying out independent reviews of products intended for use in certified organic production, handling and processing. The Organic Materials Review Institute (www.omri.org) and Pesticide Action Network North America (www.panna.org) are examples of such organisations.

By the late 1990s increasing concerns were being raised about organic agriculture following in the footsteps of industrial agriculture and losing its vision (e.g. Woodward *et al.* 1996). Examples of this are the huge growth in sales though supermarkets and increasing amounts of organic produce being transported large distances to satisfy demand in affluent countries. This concern is explored further in Ikerd (see *Special topic 3*). These concerns have resulted in a refocusing on the neglected issue of social equity (e.g. ensuring that farmers are paid a fair price for their produce). One outcome of this is the linkages formed between the Fair Trade and the organic movement (Browne *et al.* 2000). There is active debate on introducing Fair Trade requirements for European organic producers that have, to date, only been used by farmers in the third world. A practical example of reforming the links that existed between organic producers and consumers in the 1960s and 1970s are the rapid increase in 'farmers markets' in the USA and UK where traditional produce markets have been resurrected by requiring stall holders to be both local and only sell goods they have produced (Vanzetti and Wynen 2002).

In 2004, 80% of organically managed land is located in only ten countries, with more than 50% in two countries, Australia and Argentina (Yussefi 2004). However, the most intensive adoption of organic agriculture has occurred in western Europe, especially in the German-speaking countries and Scandinavia, with three countries achieving at least 10% of organic agriculture and five more countries with over 5% organic agriculture (Table 1.2). The highest numbers of organic farms are reported to be in many non-European countries, although some European countries also have over 15,000 organic farms (Table 1.3).

Most consumption takes place in affluent countries. The global organic market is estimated to be worth about US$23 billion from organic food and drinks, of which North America collects about half, Europe gets nearly half also, while only 3% of revenues are shared between all other countries (Sahota 2004). Traditional staple food products such as grains, fruit, vegetables, meat and diary products are most commonly grown, although demand for cash crops such as sugar, coffee and wine is also increasing.

Table 1.2 Percentage of national agricultural land under organic management (Yussefi 2004)

Country	Percentage (%)
Liechtenstein	26.4
Austria	11.6
Switzerland	10
Italy	8
Finland	7
Denmark	6.7
Sweden	6.1
Czech Republic	5.1
United Kingdom	4.2
Germany	4.1

Many governments today have accepted the arguments that there are problems with conventional agriculture and that organic agriculture offers a viable solution to many of these. This has resulted in policies and government actions that support the development of organic agriculture along two main pathways (Dabbert *et al.* 2001):

1 for the marketplace, or
2 for public-good environmental outcomes.

There are a numerous areas where agricultural policies have the potential to influence the adoption and success of organic agriculture (Table 1.4).

A key policy role for many governments is defining organic agriculture in law and creating enforcement mechanisms, often by using existing non-governmental certification agencies. Examples of this are the NOP in the USA and EU Regulations 2092/1991 and 1804/1999 (for crop and animal production respectively). Laws such as these are often as much for the protection of consumers as for the advancement of organic agriculture. A second policy role for many governments is the provision of direct subsidies for conversion and, in some cases, ongoing production. The use of cash subsidies for using certain farming practices is a common feature of agricultural production in many countries. In Europe especially, such incentives have been

Table 1.3 Number of farms under organic management (Yussefi 2004)

Country	No. of farms
Mexico	53,577
Italy	49,489
Indonesia	45,000
Uganda	33,900
Tanzania	26,986
Peru	23,057
Brazil	19,003
Austria	18,576
Turkey	18,385
Spain	17,751

Table 1.4 Agricultural policy mechanisms relevant to organic agriculture (after Part 3 of OECD 2003)

Providing regulatory frameworks, including review processes
Direct subsidies for conversion and on-going production or performance targets
Market facilitation (domestic and international)
Funding research, extension and educational activities
Regional development initiatives
Penalties for environmentally harmful inputs, e.g. polluting, chemical contamination
Removal of disincentives, e.g. weak labelling requirements

used for several years to encourage growers to convert to organic agriculture. Although improvements in the relative competitiveness of organic agriculture have been found and are expected to continue, it is unclear if direct payments have been the most efficient tool for improving environmental performance of farmers (OECD 2003).

More recent government policies have actively assisted and promoted organic agriculture as a means of addressing the problems of agriculture. In the UK, the Department for Environment Food and Rural Affairs (DEFRA) developed the 'action plan' to ensure stable and strategic growth for organic food production (DEFRA 2002).

Organic agriculture is now widely recognised by the public and governments as a valid alternative to conventional agriculture and is a source of ideas and approaches that conventional agriculture can adopt to make it more sustainable. However, the process of reaching this position has resulted in organic agriculture taking on some of the practices of conventional agriculture that are at odds with organic principles. A groundswell has started that is attempting to focus the organic movement on addressing these concerns; however, many of these off-farm issues, for example, food miles, may be much harder to change than what has been achieved on the farm.

The principles of organic agriculture

Development of the principles

To understand the motivations of organic farmers, the practices they use and what they want to achieve, it is important to understand the guiding principles of organic agriculture. These principles encompass the fundamental goals and caveats that are considered important for producing high quality food, fibre and other goods in an environmentally sustainable way. The principles of organic agriculture have changed with the evolution of the movement. Modern organic agriculture's alignment with the wider environmental movement has resulted in principles that have a stronger environmental focus than those from the first half of the 20th century. In addition, it is only within the last 30 years that the principles have been codified and explicitly stated. For much of organic agriculture's history, the principles were unwritten as they were inherent in the philosophy and practice of the farmers:

1 The concept of the farm as a living organism, tending towards a closed system in respect to nutrient flows but responsive and adapted to its own environment.
2 The concept of soil fertility through a 'living soil' which has the capacity to influence and transmit health through the food chain to plants, animals and [humans]; and that this can be enhanced over time.

Table 1.5 IFOAM principles of organic agriculture in 1980 (Woodward and Vogtmann 2004)

To work as much as possible within a closed system, and draw upon local resources.
To maintain the long-term fertility of soils.
To avoid all forms of pollution that may result from agricultural techniques.
To produce foodstuffs of high nutritional quality and sufficient quantity.
To reduce the use of fossil energy in agricultural practice to a minimum.
To give livestock conditions of life that conform to their physiological needs and to humanitarian principles.
To make it possible for agricultural producers to earn a living through their work and develop their potentialities as human beings.

3 The notion that these linkages constitute a whole system within which there is a dynamic yet to be understood.
4 The belief in science and an insistence that whilst these ideas might be challenging orthodox scientific thinking, they could be explored, developed and eventually explained through appropriate scientific analysis.

It was not until the organic movement became global and its arguments started gaining recognition in the wider political and social spheres that the need to articulate organic agriculture's fundamental values to outsiders arose. IFOAM has been the key organisation defining the principles of organic agriculture. The original principles created in 1980 are presented in Table 1.5.

The principles, until now, have been published at the start of the IFOAM 'basic standards' of the organic guarantee system. They served as an introduction to the standards to clarify the aims of organic agriculture (Woodward and Vogtmann 2004). The original seven principles have frequently been amended and added to over the intervening period. The process of revision has been done at the biennial General Assembly where members tabled motions for changes, which were debated and voted on. They have also been amended as part of the revision of the standards. This process has lead to the current 'principle aims of organic agriculture for production and processing'. The current list (Table 1.6) is substantially longer than the seven principles of the 1980s and they are 'principle aims' rather than principles.

In recent years there has been an increasing feeling that the principle aims have become bloated, lack consistency and have been weakened (e.g. Woodward and Vogtmann 2004). A motion passed at the IFOAM General Assembly in 2002 resulted in the world board setting up a taskforce to rewrite the principles. The results of the taskforce's work, which includes thorough consultation, will be taken to the 2005 General Assembly for acceptance. Therefore, at this time they are a work in progress with an initial draft now published. The draft principles (Table 1.7) differ notably from the current principle aims and are closer in philosophy and structure to the original 1980 principles.

In addition to this work, others have been debating and refining organic principles. As the governments in the USA were developing rules to control the production, promotion and sale of organic goods in the 1990s, Benbrook and Kirschenmann (1997) published a brief list of principles to provide a common framework for stakeholders and decision makers to base recommendations. Around the same time, the Danish Research Centre for Organic Farming (DARCOF) initiated a national debate on the principles of organic agriculture due to perceived uncertainties in existing principles and the need for clear principles to guide research planning.

Table 1.6 Objectives that IFOAM considers 'the principle aims of organic agriculture for production and processing' in 2004 (IFOAM 2002)

To produce sufficient quantities of high quality food, fibre and other products.
To work compatibly with natural cycles and living systems through the soil, plants and animals in the entire production system.
To recognise the wider social and ecological impact of and within the organic production and processing system.
To maintain and increase long-term fertility and biological activity of soils using locally adapted cultural, biological and mechanical methods as opposed to reliance on inputs.
To maintain and encourage agricultural and natural biodiversity on the farm and surrounds through the use of sustainable production systems and the protection of plant and wildlife habitats.
To maintain and conserve genetic diversity through attention to on-farm management of genetic resources.
To promote the responsible use and conservation of water and all life therein.
To use, as far as possible, renewable resources in production and processing systems and avoid pollution and waste.
To foster local and regional production and distribution.
To create a harmonious balance between crop production and animal husbandry.
To provide living conditions that allow animals to express the basic aspects of their innate behaviour.
To utilise biodegradable, recyclable and recycled packaging materials.
To provide everyone involved in organic farming and processing with a quality of life that satisfies their basic needs, within a safe, secure and healthy working environment.
To support the establishment of an entire production, processing and distribution chain which is both socially just and ecologically responsible.
To recognise the importance of, and protect and learn from, indigenous knowledge and traditional farming systems.

This resulted in a detailed discussion document (DARCOF 2000) that has been included in the IFOAM review (IFOAM 2002).

The principle of health is holistic in its outlook and takes health as more than a state of 'not being ill' but one of holism, self regulation, regeneration and balance. It applies to the whole agricultural sphere from ecosystems as a whole to the individual parts such as soil, plants, livestock and people. This principle links organic agriculture to the issues that were of concern to the founders of the organic movement in the 1920s to 1940s, which were based on human health, and is exemplified by Lady Eve Balfour's quote 'healthy soil, healthy plants, healthy people' which has become the motto of many organic organisations such as The Soil Association (UK), Soil and Health Association (NZ) and the Rodale Institute (USA). The principle also asserts that humans are an integral part of natural systems rather than being separate from them. Being an integral part of natural systems means that humans are dependent on such systems and when they are damaged there will also eventually be negative repercussions for humanity. An illustration of this thinking is the Costanza et al. (1997) seminal paper which attempted to give ecosystem services and natural capital a monetary value where they had previously been left out of, or given zero value, in economic analysis. The paper showed that the services and natural capital, such as plants providing oxygen, were 'worth' much more than the global gross national product and highlighted humankind's dependence on these services.

The ecological principle is a broader assertion of the first principle of the 1980s that states organic farmers need to work within a closed system and draw upon local resources. This

Table 1.7 IFOAM's draft revised principles of organic agriculture

Principle of Health Organic agriculture should sustain and enhance the health of soil, plant, animal and human as one and indivisible.
Ecological Principle Organic agriculture should be based on and work with living ecological systems and cycles, emulate them and help sustain them.
Principle of Fairness Organic agriculture should be built upon relationships that ensure fairness with regard to the common environment and life opportunities.
Principle of Care Organic agriculture should be managed in a precautionary and responsible manner to protect the health and well being of current and future generations and the environment.

expanded vision states that organic agriculture should function in the same way as natural ecological systems. Ecological systems are viewed as being self contained, self maintaining and self sufficient; for example, most plant nutrients are continuously cycled within the ecosystem and the systems are self-regulating, in that plant and animal populations are kept within certain limits by a multitude of both positive and negative feedback mechanisms. For farms, this means they should work within a closed system for nutrients, avoid fossil fuels, and design farming systems that are self regulating, such as growing plants that increase biological control agent populations so that they control pests, rather than using interventional techniques such as pesticides derived from natural sources.

The fairness principle is concerned with the relationships between the different groups of people involved in agriculture, such as landowners, workers and consumers, and ensuring the humane treatment of animals. Organic agriculture has always had a strong social equality dimension, and while this has had less prominence during the 1980s and 1990s, there are increasing calls for greater emphasis to be given to it. This means that workers should not be exploited and should be paid a fair wage for their work that allows them to live in a dignified manner; for farmers to be paid a fair amount for their product and for consumers to get a quality product at a reasonable price. These are issues that are also at the heart of the 'fair trade' movement, and which the organic and fair trade movements are now working closely together to implement. The principle also extends beyond the present, to include future generations, wherein the activities of the current generation should not be detrimental for future generations. Concerning livestock, the principle requires producers to treat animals in a humane and ethical manner. This is a complex and controversial area as people's views on the treatment of animals has changed considerably over recent times and differs noticeably between cultures. There is, therefore, continued discussion within the organic movement on animal rights, humane treatment of animals and even the need for livestock within organic systems. Within this debate, the focus is on ensuring that livestock are healthy, that they are kept in living conditions compatible with their physiology and natural behaviour, and that minimises stress and pain. This leads to certification standards on livestock housing design, stocking densities, avoiding feeds that an animal would not naturally eat and not breeding animals so that they have inherent problems, such as insufficient leg strength in turkeys.

The principle of care is an incarnation of the 'Precautionary Principle' based on the definition made at the Wingspread Conference Centre, Wisconsin, January 1998 (Montague 1998), 'When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically'. In practice the precautionary and care principles reverse the logic of risk management and cost benefit analysis where a proposed activity has to be proven to be harmful to prevent its use. The precautionary and care principles require activities that have the potential to be harmful to prove they are safe before they are permitted. The principle of care ensures that organic agriculture does not use new technologies that are likely to be harmful without a thorough understanding of them and measures to prevent potential harm. This approach is a pivotal reason for the organic movement banning the use of genetically modified organisms because it views the technology as having a high potential for producing unanticipated negative effects and that the cost of such effects will be paid for by people other than those benefiting from the technology. However, while organic standards do not currently permit the use of genetically modified organisms (GMOs), IFOAM World Board member Liz Clay (2003) has written about 'facing up to GMOs'. This indicates that evaluating new technologies according to the organic movement is problematic and will be subject to debate. In comparison, organic agriculture has eagerly adopted a range of new technologies, such as ensilaging grass and novel machinery, as their potential to cause unpredictable negative impacts is low, their use can be stopped and it is the user who is most likely to suffer if there are problems. The principle of care also extends to future generations and the environment as a whole, the considerations of which are often excluded from risk management and cost benefit analyses.

The principles in context

At its base, organic agriculture is a holistic/whole system approach to land management and agricultural production. This is demonstrated by the approach to pest control whereby it is the design and interaction of the farm as a whole that controls pests, compared to industrial agriculture where pests are viewed in isolation and are controlled with pesticides. This holism dates back to the beginning of organic agriculture in that the farm was viewed not as a collection of separate parts but a single, self-managing organism. This view of the farm as an organism is the origin of the term 'organic' and is based on similar logic as James Lovelock's (1979) theory of the planet as a single organism. For the earlier developers of organic agriculture, the common exchange of resources (labour, inputs and produce) between farms at the village or district scale would also have seemed natural. Now, inputs may be sourced from one country, applied in a second country by a farm worker from a third country, to produce food for a fourth country.

Organic agriculture also views humans as clearly being part of nature, not separate nor dominating or controlling it. It is from this perspective that the need for humans to work with, not against, ecological and other natural processes comes. Examples include ensuring closed nutrient cycles, using renewable energy and not producing pollutants. However, organic agriculture is embedded in the wider society, and it can only achieve such aims if the rest of society also achieves them. For example, it is difficult to work within closed nutrient cycles when the community that consumes organic produce has no effective means of returning the nutrients in the food back to the farm.

Although taking a holistic approach and wanting to work with natural systems, organic agriculture views current levels of scientific understanding/knowledge of such systems as incomplete. It takes the ecological view that such systems are phenomenally complex and at some levels, fundamentally unpredictable. This view of unpredictability is especially applicable when humans interfere and change natural systems; the concern is that the negative unpredicted effects are likely to be much greater than predicted benefits. This is an another application of the precautionary principle in that negative effects resulting from changes to ecological and other natural systems may take many decades, even centuries, to become apparent, at which point it is impossible to correct them.

Organic agriculture is also a highly ethical form of agricultural production, with clear concerns for animal and human welfare, such as ensuring that farmers get a fair return for their work and are not exploited by consumers. There is also a strong undercurrent of social justice, which forms a continuum back to the earliest organic proponents, and which is also equally strong in the 'green' movements across the globe. There is a view of agriculture being different and more fundamental from other 'industries' and there is a need for people to reconnect with agriculture. Such reconnection is considered an important step in addressing many of the social ills perceived by the organic movement.

These principles of organic agriculture are in contrast with industrial farming and the 'reductionist' approach that underlies it, where each crop can be grown in isolation and individual issues such as nutrition, pests and diseases are all addressed individually rather than part of a system. Industrial farming also exhibits a split between people and nature, with a confrontational attitude, as demonstrated by the militaristic trade names of many pesticides and herbicides, such as Invade, Ambush and Warrior! Farming is also viewed as just another means of production, which should not be afforded any more rights or limited by more obligations than other production sectors, and is not considered a fundamental part of a society (Reeve 1992).

Organic agriculture and the philosophy on which is it founded are fundamentally different from industrial agriculture and the philosophy that underlies it. This difference between them has been obscured since the 1990s by the rapid emergence of market-driven organic agriculture. To fully understand the organic movement it is essential to understand its worldview and underlying principles, which includes often radically different philosophies from that of mainstream society.

Challenges for organic agriculture

While organic agriculture aims to be environmentally sustainable, it has not yet reached its goals and there are issues that still need to be addressed. Many of these issues are reviewed in detail in other chapters of this book, including several key topics that were selected for particular analysis, such as the impact of tillage in organic agriculture and the industrialisation of organic production systems.

A common question asked of the organic movement relates to its yields (e.g. Trewavas 2004): can organic agriculture feed the world? Like questions about sustainability, productivity also depends on many factors including the farmer's background, the farm's resourcefulness and local and national support mechanisms. The appropriate answer may be: does conventional agriculture successfully feed the world now? High input-high yielding systems are currently failing to feed the world, not because of problems with productivity, but because of problems with food distribution and social organisation, and serious concerns such poverty, racism and gender imbalance (Woodward 1996).

Comparisons of organic and conventional farming have been a common feature of the organic literature since the 1980s. The researchers have looked at a wide range of measures including yield, economics, resource use efficiency, environmental impacts and social factors on a diverse range of farm types such as dairies, orchards and mixed cropping farms. Some important examples of comparative research have been published in prestigious journals, providing valuable credibility for claims that organic agriculture is productive *and* sustainable (Reganold *et al.* 1993, Drinkwater *et al.* 1998, Mäder *et al.* 2002). Additionally, numerous other studies have been published in academic journals of various disciplines (e.g. Murata and Goh 1997, Letourneau and Goldstein 2001). Some key findings from research that has examined yields suggest trends including (Wynen 1994, Stonehouse *et al.* 2001, Mendoza 2002):

- yields equivalent to or better than conventional agriculture may be achieved, although often they are not;
- yields decrease during conversion but then improve afterwards;
- organic farms have higher levels of soil biological activity and biodiversity;
- weeds can have major impact on yield in cropping systems, and specific pests and diseases can be problematic in their host crops and animals;
- some nutrients may have negative budgets for certain organic crops, depleting soil reserves of that nutrient;
- organic agriculture causes less pesticide contamination in food, people and the environment; and
- the beneficial effects of organic agriculture in food quality are unconfirmed.

Farming systems comparisons, preferably conducted over several years, supply valuable information about agricultural productivity and performance. However, they are subject to important limitations including management × site × variety interactions and externalities (e.g. energy, pollution and health) that may not be taken into account. High levels of government and commercial support have been invested over many decades in optimising plant and animal germplasm, soil fertility and pest management systems, and human capacity for conventional farming systems. This support would be expected to create substantial advantages for conventional producers.

Research methods for comparative systems trials are continually being refined, not only regarding agricultural and ecological considerations, but also social and statistical issues (van der Werf *et al.* 1997, Powell 2002). In addition to productivity, the importance of other farming systems' attributes such as resilience and stability have also been highlighted (McConnell 1992, Trenbath 1999). For example, Lotter *et al.* (2003) reported that organic maize outyielded conventional maize by significant margins in 4 out of 5 drought-affected years. A range of new frameworks are being developed for addressing externalities, environmental impacts, labour relations and so on. These frameworks include EMS (Ridley *et al.* 2003), input-output analysis (Zinck *et al.* 2004) and life cycle analysis (Brentrup *et al.* 2004).

Other, more fundamental, intrinsic differences between systems may also exist. Some farming systems attempt to do more than simply produce goods for sale. Organic farmers are required to act as stewards of the land, not just agricultural factory managers (Table 1.6). They must also observe a growing range of environmental and social restrictions, but conventional farmers are not faced with the same limitations. Wes Giblett, a biodynamic dairy farmer in Western Australia explained in a conversation recently, 'the aim is to grow topsoil', emphasising that good agricultural management as demonstrated by deepening topsoil, underpins success in sustainable farming. Wes runs the only organic dairy in Western Australia, supplying a State that is 2.5 million square kilometres – 10 times larger than Germany – with a population of almost 1.5 million. Although he has a very successful, vertically integrated dairy products business, his primary concerns about farming are topsoil, the welfare of his cows and contributing to the development of organic agriculture in his region.

Rather than limiting the analysis of organic agriculture to a comparative approach, it is more worthwhile to look for the underlying mechanisms and general principles. By identifying the strengths and weaknesses in the organic system, improvements can be made for organic farmers and relevant knowledge transferred to receptive conventional farmers. In a world of many choices, organic agriculture is a serious option for many farmers and consumers. Supporting that choice with credible science and critical evaluation is vital for improving the productivity and environmental impact of organic agriculture.

The challenges for organic agriculture will depend in part on the location and commodities being produced, but some concerns will affect organic farmers worldwide. Agronomic constraints including weeds, animal health and soil fertility continue to concern farmers. Inadequacies in regulatory and marketing structures frustrate farmers, processors and consumers alike. With limited government support, the lack of large commercial supporters and the inability of smaller commercial operations to fund research and development, extensionists and researchers are less able to attract funding.

Maintaining a commitment to the principles of organic agriculture will also be a challenge. After almost a century of development, organic agriculture has been embraced by the mainstream and shows great promise commercially, socially and environmentally. Behind the billion-dollar markets and the million-hectare farms, there are many organic growers and consumers who are deliberately opting for cleaner and safer goods that are produced with regard for the welfare of people and animals involved in production and with minimal impact on the environment.

References

Anobah, R. 2000. Development of organic market in West Africa. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *IFOAM 2000 – The World Grows Organic.* Proceedings of the 13th International IFOAM Scientific Conference. Convention Centre Basel, Switzerland 28–31 August 2000. vdf Hochschulverlag an der ETH Zurich, Basel. p. 433.

Balfour, E. 1943. *The Living Soil*. Faber and Faber, London.

Benbrook, C. and Kirschenmann, F. 1997. *Proposed Principles for Evaluating the Organic 'Rule'*. Pest Management at the Crossroads, Sandpoint, Idaho. <http://www.pmac.net/ppeor2.htm>. Accessed 12/3/04.

Brentrup, F., Küsters, J., Lammel, J., Barraclough, P. and Kuhlmann, H. 2004. Environmental impact assessment of agricultural production systems using the life cycle assessment methodology. II. The application to N fertilizer use in winter wheat production systems. *European Journal of Agronomy* 20(3): 265–279.

Browne, A.W., Harris, P.J.C., Hofny-Collins, A.H., Pasiecznik, N. and Wallace, R.R. 2000. Organic production and ethical trade: definition, practice and links. *Food Policy* 25(1): 69–89.

Carruthers, G. and Tinning, G. 2003. Where, and how, do monitoring and sustainability indicators fit into environmental management systems? *Australian Journal of Experimental Agriculture* 43(3): 307–323.

Carson, R. 1962. *Silent Spring*. Houghton Mifflin Company, Boston.

Chang, H.-S. and Kristiansen, P. 2006. Selling Australia as 'clean and green'. *Australian Journal of Agricultural and Resource Economics* 50(1): 103–113.

Clay, L. 2003. Facing up to GMO and realities. *Acres Australia* 11(1): 13.

Coffman, B. 2001. *Portrait of Global GMO Usage Update*. Monsanto, Cambridge. <http://www.monsanto.co.uk/news/ukshowlib.phtml?uid=6043>. Accessed 3/10/02.

Conford, P. 2001. *The Origins of the Organic Movement*. Floris Books, Edinburgh.

Cornish, P.S. and Stewart, T.E.B. 2002. Certification – case studies with Australian market gardeners. In: Thompson, R. (ed.) *Cultivating Communities. Proceedings of the 14th IFOAM Organic World Congress*. Victoria, Canada, 21 to 28 August 2002. Canadian Organic Growers, Ottawa. p. 222.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R., Paruelo, J., Raskin, R.G., Sutton, P. and van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253–360.

Dabbert, S., Zanoli, R. and Lampkin, N. 2001. Elements of a European action plan for organic farming. In: Ministry of Food, Agriculture and Fisheries. (ed.) *Proceedings: Organic Food and Farming – Towards Partnership and Action in Europe*. 10–11 May 2001 Copenhagen Denmark. Danish Ministry of Food, Agriculture and Fisheries, Copenhagen. pp. 199–203.

DARCOF 2000. *Principles of Organic Farming.* Danish Research Centre for Organic Farming, Foulum.

Davy, H. 1813. *Elements of Agricultural Chemistry. In a Course of Lectures for the Board of Agriculture*. W. Bulwer, London.

DEFRA 2002. *Action Plan to Develop Organic Food and Farming in England*. Department for Environment, Food and Rural Affairs, London.

Drinkwater, L.E., Wagoner, P. and Sarrantonio, M. 1998. Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature* 396: 262–265.

FAO 1999. *Organic Agriculture*. Food and Agriculture Organization of the United Nations, Rome. <http://www.fao.org/unfao/bodies/COAG/COAG15/X0075E.htm>. Accessed 26/2/99.

Fukuoka, M. 1978. *One Straw Revolution*. Rodale Press, Emmaus.

Gill, G. 2002. Book review: Ecological management of agricultural weeds. *Agriculture, Ecosystems and Environment* 90(1): 106–107.

Gliessman, S.R. 1985. Economic and ecological factors in designing and managing sustainable agroecosystems. In: Edens, T.C., Fridgen, C. and Battenfield, S.L. (eds) *Sustainable Agriculture and Integrated Farming Systems*. Michigan State University Press, East Lansing. pp. 56–63.

Grigg, D. 1989. *English Agriculture: An Historical Perspective*. Blackwell, Oxford.

Guthman, J. 2000. *Agrarian Dreams: The Paradox of Organic Farming in California*. University of California Press, Berkeley.

Haccius, M. and Lünzer, I. 2000. Organic agriculture in Germany. In: Graf, S. and Willer, H. (eds) *Organic Agriculture in Europe. Results of the Internet Project* <http://www.organic–europe.net>. Stiftung Ökologie und Landbau, Bad Dürkheim. pp. 109–128.

Halpin, D. and Brueckner, M. 2004. Organic farming in Australia. In: Willer, H. and Yussefi, M. (eds) *The World of Organic Agriculture. Statistics and Emerging Trends 2004*. International Federation of Organic Agriculture Movements, Bonn. pp. 81–85.

Howard, A. 1931 *The Waste Products of Agriculture: Their Utilization as Humus*. Oxford University Press, London.

Human Genome Project Information 2004. *Genetically Modified Foods and Organisms*. Genome Programs of the US Department of Energy Office of Science, Oak Ridge. <http://www.ornl.gov/sci/techresources/Human_Genome/elsi/gmfood.shtml>. Accessed 15/10/04.

IFOAM 2002. *IFOAM Norms – IFOAM Basic Standards + IFOAM Accreditation Criteria 2002*. International Federation of Organic Agriculture Movements, Bonn.

IFOAM 2005. *2002–2005 IFOAM World Board Made Impressive Gains for the Organic Sector*. International Federation of Organic Agriculture Movements, Tholey–Theley, Germany. <http://www.ifoam.org/press/press/Departing_World_Board.html>. Accessed 16/12/05.

Kilcher, L. 2001. Organic agriculture in Cuba: The revolution goes green. *Journal of Agriculture in the Tropics and Subtropics* 102(2): 185–189.

Lampkin, N. 1990. *Organic Farming*. Farming Press, Ipswich.

Lernoud, A.P. and Piovano, M. 2004. Latin America: country reports. In: Willer, H. and Yussefi, M. (eds) *The World of Organic Agriculture. Statistics and Emerging Trends 2004*. International Federation of Organic Agriculture Movements, Bonn. pp. 132–137, 140–147.

Letourneau, D.K. and Goldstein, B. 2001. Pest damage and arthropod community structure in organic vs. conventional tomato production in California. *Journal of Applied Ecology* 38(3): 557–570.

Lipson, M. 1997. *Searching for the 'O–Word': An Analysis of the USDA Current Research Information System (CRIS) for Pertinence to Organic Farming*. Organic Farming Research Foundation, Santa Cruz.

Lockeretz, W. 2002. Strategies for organic research. In: Powell, J. (ed.) *Proceedings of the UK Organic Research 2002 Conference: Research in Context*. 26–28 March 2002 Aberystwyth. Organic Centre Wales, Institute of Rural Studies, University of Wales Aberystwyth, Aberystwyth. pp. 25–31.

Lotter, D.W. 2003. Organic agriculture. *Journal of Sustainable Agriculture* 21(4): 59–128.

Lotter, D.W., Seidel, R. and Liebhardt, W. 2003. The performance of organic and conventional cropping systems in an extreme climate year. *American Journal of Alternative Agriculture* 18(3): 146–154.

Lovelock, J.E. 1979. *Gaia, a New Look at Life on Earth*. Oxford University Press, Oxford.

Mäder, P., Fließbach, A., Dubois, D., Gunst, L., Fried, P. and Niggli, U. 2002. Soil fertility and biodiversity in organic farming. *Science* 296(5573): 1694–1697 (and supplementary material).

Mahale, P. and Sorée, Y. 2002. National study: India. In: UNESCAP (ed.) *Organic Agriculture and Rural Poverty Alleviation. Potential and Best Practices in Asia*. United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), Bangkok. pp. 73–97.

McConnell, D.J. 1992. *The Forest-Garden Farms of Kandy, Sri Lanka*. Food and Agriculture Organization of the United Nations, Rome.

Meadows, D.H., Meadows, D.L., Randers, J. and Behrens, W.W. 1972. *Limits to Growth. A Report for the Club of Rome's Project on the Predicament of Mankind*. Universe Books, New York.

Mendoza, T.C. 2002. Comparative productivity, profitability and energy use in Organic, LEISA and Conventional rice production in the Philippines. *Livestock Research for Rural Development* 14(6). <http://www.cipav.org.co/lrrd/lrrd14/6/mend146.htm>. Accessed 15/12/05.

Merrigan, K. 2003. The role of government standards and market facilitation. In: OECD (ed.) *Organic Agriculture Sustainability, Markets and Policies*. Organisation of Economic Cooperation and Development (OECD), Paris. pp. 277–283.

Montague, P. 1998. *Rachel's Environment & Health News #586 – The Precautionary Principle*. Environmental Research Foundation, New Brunswick. <http://www.rachel.org/bulletin/pdf/Rachels_Environment_Health_News_532.pdf>. Accessed 15/11/04.

Murata, T. and Goh, K.M. 1997. Effects of cropping systems on soil organic matter in a pair of conventional and biodynamic mixed cropping farms in Canterbury, New Zealand. *Biology and Fertility of Soils* 25(4): 372–381.

Norse, D. and Tschirley, J. 2003. Agriculture and the environment: changing pressures, solutions and trade-offs. In: Bruinsma, J. (ed.) *World Agriculture: Towards 2015/2030. An FAO Perspective*. Earthscan Publications and Food and Agriculture Organization of the United Nations, London. pp. 331–356.

Northbourne, Lord. 1940. *Look to the Land*. Basis Books, London.

OECD 2001. *Improving the Environmental Performance of Agriculture. Policy Options and Market Approaches*. Organisation of Economic Cooperation and Development (OECD), Paris.

OECD 2003. *Organic Agriculture Sustainability, Markets and Policies*. Organisation of Economic Cooperation and Development, Paris.

Parrott, N. and Marsden, T. 2002. *The Real Green Revolution. Organic and Agroecological Farming in the South*. Greenpeace Environmental Trust, London.

Peroni, N. and Hanazaki, N. 2002. Current and lost diversity of cultivated varieties, especially cassava, under swidden cultivation systems in the Brazilian Atlantic Forest. *Agriculture, Ecosystems and Environment* 92(2–3): 171–183.

Powell, J. (ed.) 2002. *Proceedings of the UK Organic Research 2002 Conference: Research in Context*. 26–28 March 2002 Aberystwyth. Organic Centre Wales, Institute of Rural Studies, University of Wales Aberystwyth, Aberystwyth.

Pretty, J.N., Brett, C., Gee, D., Hine, R.E., Mason, C.F., Morison, J.I.L., Raven, H., Rayment, M.D. and van der Bijl, G. 2000. An assessment of the total external costs of UK agriculture. *Agricultural Systems* 65(2): 113–136.

Reeve, I.J. 1992. Sustainable agriculture: problems, prospects and policies. In: Lawrence, G., Vanclay, F. and Furze, B. (eds) *Agriculture, Environment and Society: Contemporary Issues for Australia*. MacMillan, South Melbourne. pp. 208–223.

Reganold, J.P., Palmer, A.S., Lockhart, J.C. and Macgregor, A.N. 1993. Soil quality and financial performance of biodynamic and conventional farms in New Zealand. *Science* 260(5106): 344–349.

Ridley, A., Paramore, T. and Seymour, E. 2003. Towards 'clean and green' farming systems using group learning to implement Environmental Management Systems. *Australian Journal of Botany* 51(6): 637–645.

Rundgren, G. 2002. History of organic certification and regulation. In: Rundgren, G. and Lockeretz, W. (eds) *IFOAM Conference on Organic Guarantee Systems – Reader. International Harmonisation and Equivalence in Organic Agriculture. 17–19 February 2002, Nuremberg, Germany*. International Federation of Organic Agriculture Movements, Tholey-Theley, Germany. pp. 5–7.

Rusch, H.P. 1964. *Bodenfruchtbarkeit*. Karl F. Haug Verlag, Heidelberg.

Sahota, A. 2004. Overview of the global market for organic food and drink. In: Willer, H. and Yussefi, M. (eds) *The World of Organic Agriculture. Statistics and Emerging Trends 2004*. International Federation of Organic Agriculture Movements, Bonn. pp. 21–26.

Schumacher, E.F. 1974. *Small is Beautiful: A Study of Economics as if People Mattered*. Abacus, London.

Setboonsarng, S. and Gilman, J. 1999. *Alternative Agriculture in Thailand and Japan*. HORIZON Communications, Yale University, New Haven, Connecticut. <http://www.solutions–site.org/cat11_sol85.htm>. Accessed 6/9/00.

Stokstad, E. 2002. Organic farms reap many benefits. *Science* 296: 1589.

Stonehouse, D.P., Clark, E.A. and Ogini, Y.A. 2001. Organic and conventional dairy farm comparisons in Ontario, Canada. *Biological Agriculture and Horticulture* 19(2): 115–125.

Thompson, R. (ed.) 2002. *Cultivating Communities. Proceedings of the 14th IFOAM Organic World Congress*. Victoria, Canada, 21–28 August 2002. Canadian Organic Growers, Ottawa.

Tovar, L.G. and Cruz, M.A.G. 2004. Mexico. In: Willer, H. and Yussefi, M. (eds) *The World of Organic Agriculture. Statistics and Emerging Trends 2004*. International Federation of Organic Agriculture Movements, Bonn. pp. 137–140.

Trenbath, B.R. 1999. Multispecies cropping systems in India: predictions of their productivity, stability, resilience and ecological sustainability. *Agroforestry Systems* 45(1–3): 81–107.

Trewavas, A. 2004. A critical assessment of organic farming-and-food assertions with particular respect to the UK and the potential environmental benefits of no-till agriculture. *Crop Protection* 23(9): 757–781.

Vandermeer, J., Van Noordwijk, M., Anderson, J., Ong, C. and Perfecto, I. 1998. Global change and multi-species agroecosystems: concepts and issues. *Agriculture, Ecosystems and Environment* 67(1): 1–22.

van der Werf, E., Kariuki, J. and Onduru, D.D. 1997. Methodological issues in comparative agro-economic on-farm research assessments of organic versus conventional farming techniques. *Biological Agriculture and Horticulture* 14(1): 53–69.

Vanzetti, D. and Wynen, E. 2002. Does it make sense to buy locally produced organic products? In: Hall, D. and Moffitt, J. (eds) *Economics of Pesticides, Sustainable Food Production and Organic Food Markets*. Elsevier, Amsterdam. pp. 195–208.

von Liebig, J. 1840. *Organic Chemistry in its Application to Agriculture and Physiology*. Taylor and Walton, London.

Walaga, C. 2000. Organic agricultural trade: the state of the art in Africa. In: Lockeretz, W. and Geier, B. (eds) *Quality and Communication for the Organic Market. Proceedings of the 6th IFOAM Trade Conference*. International Federation of Organic Agriculture Movements (IFOAM), Tholey-Theley, Germany.

WANTFA 2004. *WANTFA. New Frontiers in Agriculture*. Western Australian No-Tillage Farmers Association (WANTFA), Subiaco. <http://www.wantfa.com.au/>. Accessed 8/11/04.

Woodward, L. 1996. *Can Organic Farming Feed the World?* Elm Farm Research Centre, Newbury.

Woodward, L., Fleming, D. and Vogtmann, H. 1996. Health, sustainability and the global economy: the organic dilemma. In: Kristensen, N.H. and Hogh-Jensen, H. (eds) *New Research in Organic Agriculture, Down to Earth and Further Afield: Proceedings of the 11th International Scientific IFOAM Conference*. International Federation of Organic Agriculture Movements (IFOAM), Copenhagen.

Woodward, L. and Vogtmann, H. 2004. IFOAM's organic principles. *Ecology and Farming* 36: 24–26.

Wynen, E. 1994. Economics of organic farming in Australia. In: Lampkin, N.H. and Padel, S. (eds) *The Economics of Organic Farming: An International Perspective*. CAB International, Wallingford. pp. 185–199.

Wynen, E. 1998. *Evaluating the Potential Contribution of Organic Agriculture to Sustainability Goals*. Environment and Natural Resources Service, Research, Extension and Training Division, Sustainable Development Department, Food and Agriculture Organization of the United Nations (FAO), Rome.

Yussefi, M. 2004. Development and state of organic agriculture worldwide. In: Willer, H. and Yussefi, M. (eds) *The World of Organic Agriculture. Statistics and Emerging Trends 2004*. International Federation of Organic Agriculture Movements (IFOAM), Bonn. pp. 13–20.

Zinck, J.A., Berroterán, J.L., Farshad, A., Moameni, A., Wokabi, S. and Van Ranst, E. 2004. Issues of sustainability and sustainable land management. *Journal of Sustainable Agriculture* 23(4): 87–109.

Zong, H. 2002. National study: China. In: UNESCAP (ed.) *Organic Agriculture and Rural Poverty Alleviation. Potential and Best Practices in Asia*. United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), Bangkok. pp. 52–72.

Chapter 2

Soil fertility in organic farming systems

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Introduction

All farming systems depend on the maintenance of soil fertility for environmental and economic sustainability. The effective management of soil fertility is based on understanding processes associated with its chemical, physical and biological components, but greater emphasis has traditionally been given to soil chemical fertility. Soils vary greatly in their inherent physical and chemical characteristics and thus in their capacity to support biological activity. Of course, agricultural practices also affect soil fertility but the magnitude of change depends on specific soil and environmental conditions. Therefore, local knowledge is necessary to interpret the effects of farming practices on soil fertility.

Although organic farming has features of 'sustainable' agriculture, it cannot be assumed that organic management *per se* is more or less sustainable than some other farming systems (Reganold *et al.* 1990, Kirchmann and Thorvaldsson 2000). While all organic farming systems operate without the use of synthetic chemical inputs, many other practices used in organic farming are employed on both 'organic' and 'conventional' farms (Gosling and Shepherd 2005). Many conventional farming systems effectively address issues related to sustainability such as nutrient use efficiency, appropriateness of rotations to landform and soil type, conservation tillage, biodiversity and use of legumes (e.g. Stork and Jerie 2003, Ridley *et al.* 2004). Thus, there is a continuum in the level and nature of changes in soil characteristics associated with agricultural management practices, rather than two distinct categories of 'organic' and 'non-organic' (Parr *et al.* 1983, Drinkwater *et al.* 1995). Consequently, the concepts of sustainability and soil fertility management in organic farming systems have parallels in systems that use synthetic chemical inputs.

A key feature of organic farming systems is that they are, by necessity, very dependent on soil biological fertility, which in turn influences aspects of chemical and physical fertility. Organic farming systems aim to create temporal and spatial diversity in plant, animal and microbial life (Le Guillou and Scharpé 2000, IFOAM 2002, Treadwell *et al.* 2003). Particular emphasis is placed on creating a diverse microbial community to maximise nutrient use efficiency from poorly soluble fertilisers and promote beneficial soil physical processes (Watts *et al.* 2001, Watson *et al.* 2002b). In contrast, those farming systems that primarily use synthetic chemical fertilisers to enhance soil chemical fertility may bypass important aspects of soil biological fertility that could contribute to the chemical, as well as to physical fertility of soil (Abbott and Murphy 2003).

Current standards for organic practice may best suit chemically fertile soils in temperate climates rather than more impoverished soils in other regions. Globally, poor soils are generally dominant in tropical latitudes (Leonardos *et al.* 2000) and the most chemically fertile soils primarily occur in temperate areas (Huston 1993). Although differences in distribution of basic plant nutrients influence the extent to which farming systems are dependent on inputs, local exceptions occur within these global generalisations. Certified organic farming practices evolved in regions with chemically fertile soils (especially in Europe and North America) (Treadwell *et al.* 2003). In contrast, precursors of modern organic farming practices have been successful on chemically infertile soils for hundreds of years (e.g. in tropical soils in Africa, South America and Asia) and may include high inputs of organic matter (including animal and human waste). At the other end of the scale, great expanses of arable land are certified 'organic' primarily because of the impracticality of using synthetic inputs (e.g. vast areas of arid Australia). On a global scale, inherent soil chemical infertility is associated with the greatest plant species diversity (Huston 1993).

The results of field trials and paired comparisons (e.g. 'organic' versus 'conventional' farms) evaluating effects of organic farming systems on components of soil fertility need to be interpreted with caution (Gosling and Shepherd 2005). Long-term studies provide an opportunity for soil biological processes to stabilise. However, few of the published field trials evaluating the effect of farming systems on soil fertility have been run for longer than eight years and most have been conducted in regions with naturally chemically fertile soils and temperate climates (Table 2.1). Also, the evaluation of soil fertility in organic farming systems needs to be made at the level of specific management practices (Kirchmann and Bergström 2001, Shepherd *et al.* 2002, Stockdale *et al.* 2002, Stockdale and Cookson 2003) but this is not always practical. Both direct and indirect effects of specific management practices on the components of soil fertility should be considered to allow more complete interpretation of the impacts of soil disturbance resulting from changes in agricultural practices on soil fertility.

In this review, we consider components of soil fertility in the context of organic farming systems and how certified organic practices are used to manage soil fertility. Data from long-term field studies evaluating organic farming are discussed in terms of the components of soil fertility. The concept of soil fertility is also viewed in relation to its relevance to the application of organic farming practices across landscapes and soil types in different climatic zones.

Components of soil fertility

The use of the term 'soil fertility' is of little value unless the physical, chemical and biological properties of soil that contribute to its fertility are all considered (Abbott and Murphy 2003). There is widespread agreement as to general standards for 'good' soil physical and soil chemical fertility (which take into account different soil types), but standards for 'good' soil biological fertility are more difficult to define (Abbott and Murphy 2003). Furthermore, in contrast to chemical fertility, there are few commercial services available for farmers to measure soil physical and biological properties (Price 2001), and so the use of this information is not widespread. The greater emphasis on biological processes in organic farming means that the chemical fertility of the soil depends to a large degree on how management practices facilitate beneficial biological processes.

Soil physical fertility

Soil physical fertility contributes to the sustainability of organic farming systems by creating the framework in which biological and chemical processes supply nutrients to plants and protect soil from erosion. Soil physical fertility in organically managed systems is generally

Table 2.1 Examples of changes in soil organic matter with implementation of organic management treatments in long-term field experiments

Trial description	Changes in organic matter
Roseworthy Farming Systems Trial, South Australia Conventional, organic, biodynamic and transitional management of pasture-grain production in 440 mm y^{-1} rainfall area over 9 years. Different organic matter additions, tillage, fertiliser and rotation.	The initial soil organic C content of 1.3% increased to 1.54% in the conventional treatment and remained unchanged in the organic treatment after eight years. In the organic treatment, the negative effects on soil organic matter of tillage for weed control may have offset the benefit of incorporating 4.3 t ha^{-1} of green manure in the third year (Penfold *et al.* 1995).
DOK Trial, Switzerland Organic, biodynamic and two conventional treatments over 18 years. Treatments had identical rotation and tillage and all received manure, except one of the conventional treatments.	Compared to the beginning of the trial, soil organic matter C:N and total N remained unchanged. The initial soil organic C content of 1.7% decreased by 22% in the unmanured conventional treatment and by 13% in the manured treatments (Fließbach and Mäder 2000). The decreased light fraction C in both organic treatments compared to both conventional treatments (Fließbach and Mäder 2000) was attributed to increased organic matter decomposition (Fließbach *et al.* 2000).
Sustainable Agriculture Farming Systems Project (SAFS), California, USA Organic, integrated and conventional treatments with the same four-year rotation and one conventional two-year rotation.	Compared to baseline levels, soil organic C and N increased by 22% in the organic treatment and <1% in the conventional treatment (Clarke *et al.* 1998). Carbon inputs to the organic treatment (poultry and green manures) were 6.2 times greater than to the conventional system (Gunapala and Scow 1998). Results after the first and second rotation. The systems varied in fertiliser (synthetic or organic), winter cover crop and irrigation frequency (Gunapala and Scow 1998).
Rodale Institute Farming Systems Trial, north-east USA Conventional arable (synthetic fertiliser), organic arable (green manures) and organic mixed (green manure and manure) over 15 years.	The organic crop treatment had lower but more diverse organic matter inputs than the conventional treatment. In the organic crop treatment soil organic C and total N increased, whereas they decreased in the conventional treatment (Drinkwater *et al.* 1998).
Apple production, Washington State, USA Quantification of soil quality under conventional, integrated and organic apple production. Results 4 years after planting.	There was no difference between treatments in soil organic C content after 4 years. However, in the year following compost additions, soil organic C in the integrated and organic treatments was higher than the conventional treatment (Glover *et al.* 2000). Lack of organic matter additions was critical to the conventional treatment receiving the lowest quality rating (Reganold *et al.* 2001).
Apple production during conversion, California, USA Conventional and organic irrigated apple production. Results from the second and third years of organic management.	There was no difference in soil organic C or total N content despite 2.1 t ha^{-1} of C inputs to the organic treatment. Potentially mineralisable N was larger in the organic treatment at some sampling times (Werner 1997).

improved compared to conventional practices (Locketertz *et al.* 1981, Reganold *et al.* 1987, Reganold *et al.* 1993, Lytton-Hitchins *et al.* 1994, Siegrist *et al.* 1998, Glover *et al.* 2000, Shepherd *et al.* 2002) due to the beneficial effects of increased organic matter inputs on soil organisms and soil structure (Shepherd *et al.* 2002). Organic matter does little to improve soil aggregation, without the activities of soil organisms (Watts *et al.* 2001). Improved soil structure and root growth may be critical in organic farming systems for effectively using soil reserves of nutrients and poorly soluble fertilisers (Shepherd *et al.* 2002), and for preventing nitrogen (N) leaching from mineralising legume residues (Thorup-Kristensen 2001).

Organic farming practices do not always lead to improvements in all aspects of soil physical fertility compared to conventional practices. In some situations, soil physical characteristics are more dependent on soil type than on management (e.g. Drinkwater *et al.* 1995). Droogers *et al.* (1996) found that despite higher potential productivity (Droogers and Bouma 1996) and improvements in some measures of physical fertility, an organically managed soil had a higher probability of being compacted than a conventionally managed soil unless the farmer timed machinery traffic carefully. Although tillage practices can be similar for some organic and conventional farming systems (e.g. Droogers *et al.* 1996, Siegrist *et al.* 1998), weed control using cultivation in some organic farming systems can lead to soil structural decline, loss of soil organic matter (Gosling and Shepherd 2005) and loss of topsoil by erosion (e.g. in intensive horticultural systems).

Soil chemical fertility

The chemical fertility of soil reflects its capacity to provide a suitable chemical and nutritional environment to plants (Stockdale *et al.* 2002) and to support biological and physical processes (Abbott and Murphy 2003). The maintenance of soil chemical fertility in organic systems depends strongly on processes that govern transformations from fixed to soluble forms of nutrients (Stockdale *et al.* 2002, Watson *et al.* 2002a) such as mineralisation of organic matter and dissolution of minerals. Although these processes also occur in conventional agricultural systems, organic farms rely on them to a greater extent (Stockdale *et al.* 2002).

Traditional methods for predicting fertiliser applications for building and maintaining soil chemical fertility may not be appropriate in organic farming systems (Oberson *et al.* 1993, Condron *et al.* 2000, Watson *et al.* 2002a). Most tests of chemical fertility were developed to predict nutrient release from highly soluble sources using relationships developed between chemical extracts of soil nutrients and plant uptake (Price 2001, Watson *et al.* 2002a). These relationships may not be directly applicable to organic farming systems where:

1 nutrient sources are predominantly organic or poorly soluble and therefore slow to become available;
2 nutrient availability is more dependent on dynamic soil biological processes (Watson *et al.* 2002a); and
3 release and uptake of nutrients occurs without demonstrable changes in soil chemistry because nutrients are rapidly taken up by plants or soil microorganisms without accumulating in the soil solution.

For example, Drinkwater *et al.* (1995) found that in organic farms, although soil inorganic N was one-quarter that of conventional farms, organic N mineralisation potential was three times larger. Similarly, Oberson *et al.* (1993) concluded that routine soil tests would not have been sufficient to predict phosphorus (P) fertility due to increased mobility of P ions in a biodynamic system.

Options for monitoring soil fertility in organic farming systems may include ongoing (but time-consuming) quantification of trends in soil and plant analyses (Watson *et al.* 2002a).

Also, sequential tests may prove more useful for predicting the availability of nutrients to plants through a growing season in organic farming systems. The Organic Advisory Service in the United Kingdom performs a sequential P extraction to determine soil reserves, plant available and water soluble P (Fortune *et al.* 2001).

Combining soil analysis with nutrient budgets provides another way to monitor soil chemical fertility in organic farming systems, particularly in view of the concern that organic farming systems are mining soil nutrient reserves (Fortune *et al.* 2001, Watson *et al.* 2002b, Öborn *et al.* 2003, Oenema *et al.* 2003). Nutrient budgets quantify nutrient inputs and outputs from a defined area in a given time (Lampkin 1990, Watson *et al.* 2002b). Surpluses indicate the potential for nutrient losses to the environment and deficits suggest soil reserves of nutrients are being exploited and question the sustainability of the system in terms of soil chemical fertility (Fortune *et al.* 2001). Nutrient budgets may also be used to determine nutrient use efficiency. However, nutrient budgets may be inaccurate because it is difficult (i) to estimate the nutrient contents and application rates for manures and composts and (ii) to directly measure N fixation and leaching on commercial farms (Watson *et al.* 2002b). Nitrogen fixation is generally estimated from published studies (e.g. Drinkwater *et al.* 1998) or modelling (e.g. Korsæth and Eltun 2000), and N leaching is often excluded from nutrient budgets (e.g. Clarke *et al.* 1998).

Soil biological fertility

Soil biological fertility refers to soil processes involving organisms that improve plant growth both directly (e.g. symbioses with root nodule bacteria and mycorrhizal fungi) and indirectly, through their effects on soil chemical fertility (e.g. organic matter mineralisation and mineral dissolution) and physical fertility (e.g. soil aggregation) (Lee and Pankhurst 1992, Degens 1997). Soil biological fertility can be quantified by measuring the size, activity, diversity and function of communities. However, there are no agreed standards (Abbott and Murphy 2003, Gil-Sotres *et al.* 2005) and the full implications of increased populations, activity and diversity of soil organisms on soil function and plant growth are not known. Measures of soil biological fertility may be useful as indicators of long-term changes in overall fertility because they respond rapidly to changes in soil conditions (Nortcliff 2002).

Learning how to manage beneficial soil biological processes may be a key step towards developing sustainable agricultural systems (Lee and Pankhurst 1992, Welbaum *et al.* 2004). Central to organic farming is the aim of optimising plant production by maintaining a rich biological diversity in the soil (Le Guillou and Scharpé 2000, IFOAM 2002, Treadwell *et al.* 2003). A soil's capacity to support biological fertility is determined by inherent physical and chemical characteristics as well as management practices. The Sustainable Agriculture Farming Systems Project (SAFS) trial (see Table 2.1) showed that the relative importance of several environmental variables governing the composition of microbial communities were ranked in the order: soil type > measurement time > specific management practice > management system > spatial variation (Bossio *et al.* 1998). Management practices that may be used to maximise the benefits of soil organisms include organic matter additions, increasing plant diversity, reduced tillage practices and certain soil amendments (Lee and Pankhurst 1992, Ryan 1999, Welbaum *et al.* 2004). Without increased inputs of organic matter, neither organic nor conventional farming systems can expect to increase the size or activity of the soil biological community (Ryan 1999, Stockdale *et al.* 2001, Stockdale and Cookson 2003).

Debate surrounds the potential role of soil biological processes in maintaining soil chemical fertility in organic farming systems. In theory, the chemical fertility and sustainability of organic farming relies on soil biological fertility to a greater extent than in conventional farming systems (Le Guillou and Scharpé 2000, IFOAM 2002). The fertilisers permitted in organic farming systems are relatively insoluble in soil (IFOAM 2002) and the processes that govern their capacity to release nutrients are mediated or improved by soil organisms (Lampkin 1990, Stockdale *et al.* 2001). Organic farming may alter the function of the soil microbial community, increasing its ability to release nutrients from organic and poorly soluble sources, thereby compensating for the absence of soluble nutrient inputs (Oberson *et al.* 1993, Penfold *et al.* 1995, AQIS 1998, Ryan 1999). This may be related to a 'priming effect' (Welbaum *et al.* 2004). However, Cookson *et al.* (2005a) found that despite differences in microbial community composition and functional diversity, there was little difference in gross mineralisation rates between the organic and conventional arable farming systems. Other field work showed that there was no difference in the response of crops grown in organically and conventionally managed soil to rock phosphate application, indicating that organic management had not increased the availability of rock phosphate to crops (Dann *et al.* 1996, Ryan and Ash 1999). Further research is needed to scientifically investigate the exact nature of biological activities under long-term organic and conventionally managed farming systems, especially in soils that are highly weathered.

Practices that enhance function of arbuscular mycorrhizal (AM) fungi and root nodule bacteria have potential to improve some aspects of soil biological and chemical fertility. Plant breeding for greater dependency on these symbioses could be equally important (Smith *et al.* 1992, Ryan and Graham 2002, Marschner and Rengel 2003). AM fungi have the potential to access P in soil pores unavailable to plant roots (Schweiger 1993), but it is not known whether this mechanism has a significant effect in overcoming P deficiency. AM fungi can also improve plant availability of poorly soluble P sources such as rock phosphate and P adsorbed in soil (Barrow *et al.* 1977, Pairunan *et al.* 1980) by enabling plants to have access to P as soon as it is released into the soil solution. Under organic farming practices, the extent of root colonisation by AM fungi may be greater due to decreased use of soluble P fertilisers (Ryan *et al.* 1994, Mäder *et al.* 2000, Ryan *et al.* 2000) and the diversity of AM fungi can be greater (Oehl *et al.* 2004b). However, the benefits of AM fungi to plant production and sustainability are very difficult to measure (Jakobsen *et al.* 2001) and appear to be environmentally dependent (Thompson 1987, 1990, Ryan and Graham 2002, Ryan and Angus 2003).

It may be possible to selectively increase the abundance and activity of certain soil organisms using agricultural inputs. For example, simple organic compounds such as sugars and complex humic substances may stimulate microbial activity, leading to short-term increases in biological activity and, potentially, to nutrient release and improved physical fertility (Welbaum *et al.* 2004). Gleeson *et al.* (2005a, 2005b) demonstrated that specific fungi and bacteria occurred preferentially on different silicate minerals. This observation is very significant if microorganisms preferentially stimulated in this manner have beneficial effects on soil fertility. While further understanding of the dynamics and diversity of soil biological processes is necessary in all farming systems, a soil may have 'too much' biological activity. This can occur if organic matter is continuously disturbed and exposed to rapid degradation, with subsequent loss of its value as a slow release nutrient source and contributor to maintaining or improving soil structure.

Managing soil fertility in organic farming systems

Underlying principles

The practices used to manage soil fertility in organic farming systems should be understood in terms of the aims and underlying principles on which they are based. This has been discussed in various reviews of aspects of organic farming systems (Stockdale *et al.* 2001, Shepherd *et al.* 2002, Stockdale *et al.* 2002, Watson *et al.* 2002a) and in organic production standards (e.g. Le

Guillou and Scharpé 2000, IFOAM 2002). To achieve the long-term goal of sustainability, organic farming systems aim, as far as possible, to be self-sufficient for nutrients and organic matter by producing and reusing materials on-farm. Therefore, practices that facilitate the efficient re-use of nutrients and organic matter within the farm are stressed. Also, organic production standards only permit non-synthetic fertilisers that are poorly soluble in the soil solution. Nutrient management in organic farming systems is not simply replacement of soluble fertilisers with insoluble fertilisers (Lampkin 1990, IFOAM 2002). To build and maintain adequate soil fertility, organic farming systems must integrate management practices such as those discussed below.

The unscientific nature of the ban on manufactured inputs in certified organic farming systems has been criticised (Kirchmann 1994, Kirchmann and Thorvaldsson 2000, Kirchmann and Ryan 2004), but the contrary practice of seeking to maximise crop yield using synthetic inputs regardless of the environmental consequences is not scientifically based either (Doran *et al.* 1996, Leonardos *et al.* 2000). The design of treatments in Wells *et al.* (2000) shows how a farmer's bias towards achieving certain objectives from production influences management choices. However, it is not the purpose of this review to justify the underlying assumptions of organic farming systems, but rather to discuss their effects on soil fertility.

Although it has been claimed that organic farming systems are fundamentally different from other systems, this cannot be substantiated from a soil fertility perspective. The management of soil fertility in organic farming systems is variously characterised by mixed livestock-arable systems, crop rotations, legumes, organic matter inputs and the use of fertilisers that are not readily soluble in soil (Stockdale *et al.* 2001); similar practices also characterise conventional farming systems that address sustainability issues, including the use of legumes to manage plant and animal nutrition in broadacre livestock–crop production (Puckridge and French 1983) and crop and forage rotations to manage pests and soil fertility.

Livestock

Livestock can directly improve soil chemical and biological fertility by introducing organic matter and nutrients in manure and urine (Watson *et al.* 2002a). Although animal traffic may decrease some aspects of soil physical fertility (Watson *et al.* 2002a), the reduced tillage, dense rooting, increased root exudation and soil organic matter content associated with pasture phases (Nguyen *et al.* 1995, Murata and Goh 1997) increases soil aggregation and biological fertility and reduces erosion (Robertson and Morgan 1996, Breland and Eltun 1999, Eltun *et al.* 2002). Livestock can also help to control weeds (Penfold 1997) which may reduce chemical fertility by competing with plants for nutrients. The use of manure helps to achieve the aim of self-sufficiency in nutrients and organic matter, but it is not always available in large quantities (Condron *et al.* 2000) and its management during storage and handling needs to minimise gaseous and leaching losses of nutrients (Lampkin 1990).

Rotations that include livestock can be a key component of sustainable farming systems. The retention of mixed farming in organic farming systems and the associated increases in spatial and temporal habitat heterogeneity was partly responsible for increased diversity of organisms observed on organic farms, from soil microbes to mammals and birds (Hole *et al.* 2005). Without livestock, it can be difficult to manage nutrients, particularly N, in organic farms (Lockeretz *et al.* 1981, Lampkin 1990, Fortune *et al.* 2001, ‚Stockdale *et al.* 2001) but dairy farms may be an exception to this because of their susceptibility to N losses (Watson *et al.* 2002a).

Legumes

Legumes are a fundamental component of organic farming systems (in pastures, green manures, cover crops or food crops) because they reduce or eliminate the need for external N fertilisers (Stockdale *et al.* 2001) providing they are effectively nodulated. The sustainability of legume use to supply crops with N in either organic or conventional farming systems (Ridley *et al.* 2004) depends on the:

1 fixation of sufficient N in the legume biomass;
2 ability of the soil community to increase mineralisation of organic N; and
3 capacity of farming practices to maximise the beneficial soil fertility and environmental effects of legumes and minimise their negative effects (e.g. increased acidity and N leaching).

Nitrogen fixation by legume biomass may be efficient but the availability of the residues to subsequent crops could be improved. Watson *et al.* (2002b) reviewed farm-scale nutrient budgets for 88 organic farms in temperate climates and found that although all of the N budgets showed a surplus, N use efficiency was low (average 0.3). Similarly, in another review, Berry *et al.* (2002) concluded that although legumes had the potential to supply sufficient N to crops, there was usually a shortfall. Where legume pastures are incorporated only once every few years, organically produced crop residues and manures tend to have low N contents and slow mineralisation rates. Improving legume-N availability to subsequent crops could be achieved by (i) careful timing of organic residue incorporation, (ii) management practices that improve the quality of legumes as microbial substrates and (iii) matching crop type with N mineralisation dynamics (Berry *et al.* 2002).

For legumes to maintain adequate N availability to plants, reductions in soluble N inputs must be compensated for by increased mineralisation of organic N (Bloem *et al.* 1994). Potentially mineralisable N is frequently higher in organic farming systems (Reganold *et al.* 1993, Drinkwater *et al.* 1995, Gunapala and Scow 1998, Liebig and Doran 1999, Hauggaard-Nielsen *et al.* 2003). Bloem *et al.* (1994) attributed the higher average rates of N mineralisation (30%) for integrated compared with conventional farming to higher soil organic matter contents, but there was no difference in gross N transformations between a pair of organic and conventional arable farms (Cookson *et al.* 2005a). Mite diversity in a conventional soil under wheat was correlated with gross N immobilisation (Osler *et al.* 2004), so this may also be relevant in organic farming systems because mites can increase the diversity of soil fauna (Mäder *et al.* 2002, Hole *et al.* 2005).

The sustainability of using legumes to supply crop requirements for N also depends on the capacity of organic management practices to maximise beneficial effects of legumes while minimising the potential for N leaching. Intercropping with legumes can increase the efficiency with which soil nutrients are used (Hauggaard-Nielsen *et al.* 2003). Steen Jensen and Hauggaard-Nielsen (2003) advocated increased use of legumes in farming systems because of beneficial environmental effects including improved soil structure, erosion protection, increased biological diversity, stimulation of rhizosphere organisms, acidification of alkaline soils and reduced energy use and carbon dioxide (CO_2) production on and off the farm. However, asynchrony in plant demand for N and its release from organic matter can cause nitrate leaching, especially post harvest, and the acidifying effect of legumes is detrimental in acid soils (Fillery 2001, Steen Jensen and Hauggaard-Nielsen 2003, Ridley *et al.* 2004). Kirchmann and Bergström (2001) reviewed nitrate leaching from organic and conventional farms. They concluded that although the average nitrate leaching over a rotation was lower in the organic systems investigated, when the lower intensity of N input in organic farming was taken into account, there was no difference (Kirchmann and Bergström 2001). In this evaluation, there were insufficient data to compare nitrate leaching based on yield. Management options for controlling N leaching were discussed by Kristensen *et al.* (1995), Steen Jensen and Hauggaard-Nielsen (2003) and Ridley *et al.* (2004) and well-managed organic systems have the potential to use excess N though practices such as catch crops (Thorup-Kristensen 2001) and by intercropping (Hauggaard-Nielson *et al.* 2003).

Rotations

Rotations facilitate processes that alleviate some of the fertility constraints to production that are addressed in conventional farming systems by use of synthetic inputs (Lampkin 1990, Reganold *et al.* 1990). Organic rotations may include greater use of green manures and cover crops (Reganold *et al.* 1987, Drinkwater *et al.* 1995), emphasise different regional crops (Lockeretz *et al.* 1981), and have longer pasture phases (Murata and Goh 1997, Derrick and Dumaresq 1999, Kirchmann and Bergström 2001, Deria *et al.* 2003) than on conventional farms, leading to higher plant diversity in space and time (Stockdale *et al.* 2001). Rotations are also used to manage soil physical fertility by emphasising inputs of organic matter from pasture phases, green manures or cover crops.

Organic matter management

Organic matter incorporation into soil in organic farming systems is pivotal to increasing chemical fertility and improving soil structure and this has been extensively investigated (Ryan 1999, Goulding *et al.* 2001, Watson *et al.* 2002a, Stockdale and Cookson 2003). Organic farming systems emphasise frequent additions of diverse sources of organic matter from catch crops, crop residues, manures, some forms of organic fertiliser and perennial crops (Reganold *et al.* 1990, Drinkwater *et al.* 1998). Numerous paired comparisons of organic and conventional farms demonstrated that under organic farming practices, soil organic carbon (C) content increased by up to 30% (Lockeretz *et al.* 1981, Lytton-Hitchins *et al.* 1994, Drinkwater *et al.* 1995, Nguyen *et al.* 1995, Droogers *et al.* 1996) and total N content also increased (Bolton *et al.* 1985, Reganold *et al.* 1993, Drinkwater *et al.* 1995, Muratah and Goh 1997, Liebig and Doran 1999). Examples of more substantial increases in soil organic C content (up to 200%) are probably due to the comparisons being limited to a single organic and conventional farm (Gerhardt *et al.* 1997, Jordahl and Karlen 1993) or to assessment immediately following large inputs of organic matter (Wells *et al.* 2000).

Apart from benefits to chemical and physical fertility, whether or not organic farming systems increase organic matter inputs relative to conventional farming systems determines their ability to increase soil biological activity (Ryan 1999, Stockdale and Cookson 2003). Increases in the abundance, activity and diversity of soil organisms under organic management are primarily caused by increases in the amount and quality of organic matter inputs (Robertson and Morgan 1996, Yeates *et al.* 1997, Ryan 1999, Stockdale and Cookson 2003, Cookson *et al.* 2005a,b, Hole *et al.* 2005). In some situations, the higher soil organic matter contents under organic farming increased microbial biomass and activity by increasing soil water content (Robertson and Morgan 1996, Fraser *et al.* 1998).

The difficulty in increasing soil organic matter content in some environments may threaten the sustainability of organic farming systems. In semi-arid environments with high temperatures and low precipitation, C and N inputs to soil may be low and organic matter content unrelated to soil texture (Hassink 1997, Ryan 1999). Also, the degradation of organic inputs may be very rapid in these environments if the soils are sandy, because they offer little protection to organic matter. Several Australian studies showed that compared to conventional farms, organic management did not increase soil organic C in dryland grain–livestock production in southern Australia (Penfold *et al.* 1995, Derrick and Dumaresq 1999, Deria *et al.* 2003). In contrast, soil organic C did increase in irrigated organic farming systems (Lytton-Hitchins *et al.* 1994, Wells *et al.* 2000). The reasons organic farming may not always increase soil organic C contents include (Gosling and Shepherd 2005):

1 the larger yields and more intense animal production in conventional systems increasing organic matter inputs;
2 the smaller C:N ratio of organic leys causing them to decompose more quickly; and
3 more intensive cultivation for weed control.

Organic farming systems that fail to increase levels of soil organic matter cannot be expected to increase overall soil biological activity. Further research is needed to investigate the role of organic matter and soil biological fertility in the sustainability of organic farming systems in semi-arid environments with highly weathered soils, especially in relation to organic certification standards.

Fertilisers

The fertilisers permitted in certified organic farming systems, and in some cases the amount that may be applied, are restricted by organic certification standards. They are loosely divided into two categories: (i) naturally occurring geological resources (minerals) and (ii) organic materials. Minerals permitted as fertilisers in organic farming systems include lime, gypsum, rock phosphate, guano, elemental sulfur (S), dolomite and various ground silicate minerals. Organic materials include those produced on farms such as green manure, animal manure and compost, as well as off-farm sources such as fish, blood and bone meal, seaweed extracts and microbial products. Complete lists of fertilisers permitted in organic farming systems can be found in the various organic certification standards. Some restrictions may not be based on scientific evaluations. For example, the allowable level of organic matter (e.g. as compost) may be less than that required in poor sandy soils. In Australia, the National Association for Sustainable Agriculture Australia (NASAA) limits off-farm manure and compost applications to 15 and 20 t ha^{-1} y^{-1} respectively (NASAA 2003) and the European Union standards limit manure application to 170 kg N ha^{-1} y^{-1} (Watson *et al.* 2002b).

Estimation of the relative effectiveness of nutrient sources can be a useful way in which to estimate their efficacy as fertilisers (Barrow 1985). The relative effectiveness of alternative nutrient sources is usually calculated by comparing the yield plateau of the response curve of the fertiliser in question to a soluble source of the same nutrients (Barrow 1985). For minerals used as nutrient inputs in organic farming systems their relative effectiveness is almost always <1 due to low solubility in soil. Organic matter inputs can also be evaluated in terms of their relative effectiveness based on their recalcitrance, but of equal importance is the extent to which they are physically protected from degradation in soil aggregates (Strong *et al.* 1999), which would be different in different soil types.

Silicate minerals and rocks composed of silicate minerals are used in organic farming as fertilisers and soil ameliorants. Silicate minerals are the main components of igneous and many metamorphic rocks and vary in their composition and dissolution rates. Dissolution is favoured by minerals of small grain size (Gillman 1980, Niwas *et al.* 1987, Gillman *et al.* 2001 2002,) and large surface area and is greater in soils with low pH, high moisture and temperature and soil solutions that are not in equilibrium with mineral surfaces (Harley and Gilkes 2000). Silicate minerals are most suitable as fertilisers in highly weathered, tropical soils where acidic, nutrient deficient soils and heavy rainfall events favour dissolution and also in leaching soils, particularly sands (Leonardos *et al.* 1987, Coroneos *et al.* 1996, Hinsinger *et al.* 1996, Harley and Gilkes 2000). In addition to a soil's capacity to dissolve silicate minerals due to inherent chemical and physical characteristics, plants and microorganisms increase silicate mineral dissolution (Barker *et al.* 1997, Hinsinger *et al.* 2001). They release organic ligands which attack mineral surfaces and form complexes and lower soil pH by releasing H^+ ions and organic acids into the soil. Nutrient uptake by plants prevents equilibrium between minerals and soil solution from being reached, which stimulates further dissolution (Barker *et al.* 1997, Hinsinger 1998, Harley and Gilkes 2000, Wang *et al.* 2000).

Research on plant uptake of nutrients in silicate minerals has focused on release of K and several researchers have concluded that silicate minerals have potential as slow release fertilisers (Gillman 1980, Coroneos *et al.* 1996, Hinsinger *et al.* 1996, Hildebrand and Schack-Kirchner 2000), but rocks and minerals high in silica (e.g. granite and feldspar) may be poor sources of potassium (Blum *et al.* 1989, Bakken *et al.* 1997, Bakken *et al.* 2000). When the dissolution of ground granite in 20 acid soils from Western Australia was measured, few soils showed an increase in exchangeable calcium (Ca) or magnesium (Mg) and nine soils showed an increase in exchangeable potassium (K) (Hinsinger *et al.* 1996). Incubation experiments and field and pot trials have shown that between 1 and 10% of the K in feldspar is released up to 14 months after application (Sans Scovino and Rowell 1988, Coroneos *et al.* 1996, Hinsinger *et al.* 1996,) and the relative effectiveness of granite as a potassium fertiliser was <0.14 compared to KCl (Bolland and Baker 2000).

Silicate minerals may also provide plants with Ca, Mg and some micronutrients. Studies have measured the release of Ca and Mg from silicate minerals and rocks such as amphibolite, basalt, diabase, dunite, gneiss, granite, phenolite, serpentine, syenite and a volcanic ash (Chittendon *et al.* 1964, Chittendon *et al.* 1967, Gillman 1980, von Fragstein *et al.* 1988, Blum *et al.* 1989, Gillman *et al.* 2001). Chittendon *et al.* (1967) showed that on an equal weight basis the Mg content of tobacco, white clover and ryegrass plants increased in the order dolomite < serpentine < dunite. Application rates between 1 and 50 t ha^{-1} of basalt increased the exchangeable K, Ca and Mg in seven highly weathered tropical soils in Queensland, Australia (Gillman *et al.* 2001). For five soils, 5 t ha^{-1} of basalt increased exchangeable cations but on one soil, 1 t ha^{-1} of basalt was sufficient to increase exchangeable Mg. Silicate minerals also contain plant micronutrients but very little work has been done to assess their plant availability. Certain silicate rocks in both water and 0.1 M hydrochloric acid (HCl) released iron and manganese to a greater extent than copper and zinc (von Fragstein *et al.* 1988).

In contrast to their use as nutrients, silicate minerals have been advocated as soil ameliorants (Harley and Gilkes 2000, Hildebrand and Schack-Kirchner 2000) especially for lateritic soils in tropical climates (Leonardos *et al.* 1987, Leonardos *et al.* 2000, Gillman *et al.* 2001). Silicate minerals increase soil pH, although not as effectively as lime and to varying degrees on different soils (Gillman 1980, von Mersi *et al.* 1992, Hinsinger *et al.* 1996, Hildebrand and Schack-Kirchner 2000). Gillman *et al.* (2001) found that after nine months, granite applied to a highly weathered soil at 300 t ha^{-1} increased the soil cation exchange capacity from 9 to 14 meq/100 g of soil. Ground silicate minerals may also increase water-holding capacity (Kahnt *et al.* 1986). The highly weathered soils in tropical climates have most to gain from the use of silicate minerals as soil ameliorants.

For organic farming systems that do not have access to adequate quantities of manure to balance P lost from soil in harvested products, rock phosphate (and guano) may be used. The use of phosphate rocks and factors affecting their relative effectiveness were reviewed by Khasawneh and Doll (1978). Their relative effectiveness is affected by mineral properties (reactivity, particle size, surface area), soil factors (pH, titratable acidity, P and Ca availability and retention, sand content, organic matter content, moisture and temperature) and plant factors (P and Ca demand, root structure, rhizosphere pH) (Kanobo and Gilkes 1987, Kanobo and Gilkes 1988, Hughes and Gilkes 1994, Hinsinger and Gilkes 1997). Although many of the factors affecting rock phosphate dissolution are known, it is not easy to predict their relative effectiveness. Sources of rock phosphate have unique reactivity, for which citrate solubility has become a standard test. In an evaluation of the relative effectiveness of 14 rock phosphates, differences in rock phosphate reactivity caused a ten-fold difference in dry matter yield between the least and most reactive (Léon *et al.* 1986). However, the relative effectiveness also depends on the particular soil and plant factors and can result in a rock phosphate being as effective as superphosphate or nearly inert (Khasawneh and Doll 1978).

There is potential to increase the relative effectiveness of poorly soluble minerals by managing soil biological processes. As already mentioned, plant availability of rock phosphate can be improved by AM fungi (Barrow *et al.* 1977, Pairunan *et al.* 1980), and some soil micro-organisms can solubilise P (Richardson 2001) and increase the dissolution of silicate minerals (Barker *et al.* 1997). Rogers and Bennet (2004) showed that in a P limiting environment, micro-organisms selectively colonised the surface of minerals containing P. The ability of these processes to increase nutrient availability to plants might be maximised if specific practices and inputs can be found to target and increase populations of soil organisms involved. Alternatively, plant species and varieties may be chosen that cause the greatest mineral dissolution (Wang *et al.* 2000). Also, because the mechanisms by which plants cause mineral dissolution can be stimulated by nutrient deficiencies, breeding plant varieties in suboptimal nutrient conditions may produce varieties with greater capacity to dissolve minerals and to form associations with more beneficial AM fungi (Hinsinger 2001, Ryan and Graham 2002, Marschner and Rengel 2003).

Other procedures for increasing the effectiveness of silicate minerals and rock phosphates involve altering the minerals themselves. High-energy milling (ball-milling at high energy intensities) causes changes to mineral structure and bonding, and is acceptable under organic production standards. Compared to unmilled rock phosphates, high-energy milling increased the relative effectiveness of five rock phosphates by up to three times (Lim *et al.* 2003). High energy milling for 120 minutes increased the release of Ca and Mg from basalt and dolerite from 2% to about 18% (Priyono and Gilkes 2004). The rapidly dissolved K from feldspar was increased from 0% to 27% by 120 minutes of high-energy milling. Co-composting rock phosphates and silicate minerals (Garcia-Gomez *et al.* 2002) may also increase their relative effectiveness, by increasing their exposure to microbial processes that cause their dissolution, but more rigorous research is needed to confirm this. Others have demonstrated that shaking silicate minerals in organic extracts that are readily available to farmers, such as brewer's yeast and cattle urine, increased the amount of Ca, Mg and K released from silicate minerals (von Fragstein and Vogtmann 1983).

Very little work has been published about micronutrients in organic farming systems. Condron *et al.* (2000) concluded that organic farming might be unsustainable on soils deficient in micronutrients unless measures are taken to supply them in fertilisers. Seaweed extracts can provide plants with micronutrients and opportunities exist to optimise their use. However, little is known about the optimum time to harvest seaweeds or the nutrient content of different species and their nutrient content is not high enough to meet crop demands (Verkleij 1992, Edmeades 2002). Furthermore, they may stimulate plant growth and yield through action of plant hormones rather than nutrients (Verkleij 1992). Micronutrient nutrition of livestock can be maintained by growing pasture species rich in trace elements (Condron *et al.* 2000), but this requires further investigation.

Organic farming has the potential to exploit soil reserves of nutrients and may, therefore, be considered unsustainable (Derrick and Dumaresq 1999, Kirchmann and Ryan 2004, Gosling and Shepherd 2005). In some cases, nutrients 'mined' in organic farming systems were previously added as fertiliser when the land was farmed using conventional practices. Published nutrient budgets comparing organic and conventional farms have focused on N, P and K. They indicate that it is possible to balance nutrient budgets in organic farming systems (Fortune *et al.* 2001, Watson *et al.* 2002b), but that budgets are often negative because nutrients are not adequately replaced (Gosling and Shepherd 2005, Nguyen *et al.* 1995).

Outside of temperate climates, it may be more difficult to maintain levels of soil nutrients because manure is less readily available (Condron *et al.* 2000). Several Australian studies have reported that P availability limits production on organic livestock–crop farms and threatens the sustainability of organic farming systems in Australia (Dann *et al.* 1996, Derrick and Dumaresq 1999, Ryan and Ash 1999, Deria *et al.* 2003). Deria *et al.* (2003) noted that several of the organic grain–livestock farms in their study did not use fertilisers and that those that did used only small amounts of poultry manure (40 kg ha^{-1}). In a comparison of organic and conventional mixed livestock–cereal farms in New Zealand, the N budgets were balanced by the use of legumes (Nguyen *et al.* 1995), while P and S budgets were balanced on the farms that used compost, rock phosphate and elemental S and negative on the farms that did not. Clearly, this is an area that requires further research and highlights the potentially vital role of soil microorganisms in organic farming systems if they can be managed to more effectively cycle nutrients.

Considerable commercial attention is being given to development of microbial products that can be added to soil to stimulate release of nutrients and benefit plant growth in organic farming systems (Welbaum *et al.* 2004). Many other forms of organic (plant, animal and microbial) fertilisers are permitted, but most have not been scientifically investigated under field conditions. Further research is required to validate the capacity of these materials to enhance soil fertility in the long term and in combination with other management practices, using well-replicated scientific studies, otherwise claimed effects will remain anecdotal.

Long-term effects

Several published long-term field trials have assessed aspects of soil fertility for a range of organic and conventional treatments (Table 2.1). Although these studies cannot compare management at a whole farm level, this has been addressed in studies using paired comparisons (e.g. adjacent farms). Examples of changes in physical, chemical and biological aspects of soil fertility from some of the field trials are listed in Table 2.2. Drinkwater *et al.* (1995) showed that differences in soil fertility were time dependent and were more pronounced in fields with greater than four years of organic management compared to those with less than three. Gosling and Shepherd (2005) suggested that ten years was insufficient to observe changes in soil levels of nutrients.

Many of the proposed benefits of organic farming systems depend on their ability to increase soil organic C (Table 2.1), but not all field trials have confirmed that organic farming systems increase soil organic C content (e.g. the Roseworthy trial). The Californian apple trial had stable soil organic C content despite C inputs of 2.1 t ha^{-1} greater than the conventional treatment over three years. In this case, measurements were taken in only the second and third years of organic management (Werner 1997) and total organic C content can take many years to change.

In the SAFS trial (Table 2.2), potentially mineralisable N was higher in the organic treatment than the conventional treatment only after the incorporation of a green manure crop (Gunapala and Scow 1998). Differences in organic matter quality between the organic treatments were evident in the Rodale trial where the use of manure in the organic crop–livestock treatment increased mineralisable C and N compared to the organic crop rotation (Wander *et al.* 1995). In the Rodale trial differences in organic matter quality between the organic treatments were evident where the use of manure in the organic crop–livestock treatment increased mineralisable C and N compared to the organic crop rotation (Wander *et al.* 1995).

In the Apelsvoll trial (Table 2.2), biological activity increased during the pasture phases (Breland and Eltun 1999). However, the Roseworthy trial showed very few differences between systems in soil biological fertility (measured as root colonisation by AM fungi, microbial

Table 2.2 Examples of differences in soil physical, biological and chemical characteristics of soil fertility in long-term field trials that include organic farming treatments

Trial description (see Table 2.1 for details)	Physical fertility	Biological fertility	Chemical fertility
Roseworthy Farming Systems Trial, South Australia	There was higher infiltration and lower soil loss in the treatments with stubble retained. In the integrated treatment there was less infiltration and greater soil loss (after 4 years) due to lack of disturbance of surface crust and stock trampling. There was no difference between treatments in water-stable aggregation (Penfold *et al.* 1995).	There was no significant difference between treatments in microbial biomass, cotton strip tensile strength, or earthworms.	Compared to initial soil levels, extractable P increased by 19% in the conventional treatment and declined by 9 and 12% in the organic and biodynamic treatments respectively, as a result of lower inputs and less soluble fertilisers. The P budget for biodynamic treatment was negative. There was no difference between treatments in exchangeable cations or DTPA extractable ions (Penfold *et al.* 1995).
DOK Trial, Switzerland	There was no difference between treatments in bulk density, splash erosion, volume of total or large pores. Aggregate stability (percolation method) was 10 to 60% higher in both organic treatements than in either conventional treatment, indicating lower erodibility (Siegrist *et al.* 1998).	Compared to the conventional treatment, the organic treatment showed higher microbial biomass C and N, mycorrhizal colonisation, enzyme activities (Fließbach and Mäder 2000), earthworm biomass and density (Siegrist *et al.* 1998) and microbial, faunal and plant diversity (Mäder *et al.* 2002). In the laboratory, there was over 10% greater organic matter decomposition in the biodynamic soil than in the conventional soils (Fließbach *et al.* 2000).	Available P was adequate but decreased in all except the synthetic fertiliser treatment. The average P budgets (kg P ha^{-1} y^{-1}) were 3.8 for synthetic fertilisers only, –5.0 for synthetic fertilisers and manure, –5.7 for organic and –7.8 for biodynamic (Oehl *et al.* 2002).

Trial description (see Table 2.1 for details)	Physical fertility	Biological fertility	Chemical fertility
Apelsvoll Cropping System Experiment, Norway	Reductions in soil loss were related to the use of perennial grasses in mixed systems rather than to organic or conventional management (Eltun *et al.* 2002).	Microbial biomass C and N and earthworm abundance were higher in the mixed treatments and in the organic arable treatment than in the conventional and integrated arable treatments, as a result of the use of leys, manure and green manure (Breland and Eltun 1999, Eltun *et al.* 2002).	N, P and K budgets were increasingly negative in the order conventional, integrated, organic. Except for lower extractable P in the organic arable soil, there were no measurable changes in plant nutrients (Eltun *et al.* 2002). The two organic treatments had the largest net reduction in soil N but the lowest N leaching.
Sustainable Agriculture Farming Systems Project (SAFS), California, USA		The organic treatment had higher microbial biomass C and N, enzyme activity and potentially mineralisable N (Gunapala and Scow 1998) and different microbial community composition phospholipid fatty acid than the conventional treatment (Bossio *et al.* 1998). There were minimal differences between treatments in residue decomposition (Gunapala *et al.* 1998). Cover crops and higher irrigation frequency in the organic treatment may have contributed to the differences (Gunapala and Scow 1998).	The organic treatment had higher soluble P and exchangeable K and lower soluble Ca and Mg. Most differences in soil nutrients are explained by differences in inputs (Clarke *et al.* 1998).

Trial description (see Table 2.1 for details)	Physical fertility	Biological fertility	Chemical fertility
Apple production, Washington State USA	The organic treatment had lower bulk density than the other treatments owing to 2 t ha^{-1} compost additions and tillage for weed control. Compared to the conventional treatment, aggregate stability was higher in the integrated and not different in the organic treatments. Although the organic treatment received twice as much compost as the integrated treatment, the negative effects of tillage on aggregate stability offset the benefits of the compost (Glover *et al.* 2000).	There was higher microbial biomass C in organic and integrated treatments due to compost additions, but no differences in biomass N, microbial respiration or earthworm populations (Glover *et al.* 2000).	There was no difference between organic and conventional treatments in total N, nitrate, extractable P (Glover *et al.* 2000) or leaf tissue nutrient contents (Reganold *et al.* 2001).
Apple production during conversion, California, USA	At some sampling times, the organic treatment had lower bulk density and higher water holding capacity than the conventional treatment (Werner 1997).	At some sampling times microbial biomass C was higher in the organic treatment than the conventional treatment. Mycorrhizal colonisation of roots was consistently higher in the organic treatment than the conventional treatment. There were no differences between treatments in earthworm density or soil-surface arthropod diversity or abundance (Werner 1997).	There was no significant difference between treatments in extractable P (Werner 1997).

biomass C, earthworm numbers, loss of tensile strength in buried cloth) (Penfold *et al.* 1995). Research is needed to determine the effect on the sustainability of organic farming systems in semi-arid areas where it is difficult to increase soil organic matter contents or biological activity. It is still unclear whether species diversity is, as is often proposed, critical to the integrity and long-term sustainability of soil ecosystems (Welbaum *et al.* 2004).

Further research is needed to evaluate the claim that organic farming systems alter the function of the soil biological community to compensate for the absence of soluble fertilisers (Oberson *et al.* 1993, Penfold *et al.* 1995, AQIS 1998, Ryan 1999). In the SAFS trial, decomposition rates in a laboratory comparison of organic and conventional soils were similar, but cover crop decomposition was more consistent over time in organically managed soil (Gunapala *et al.* 1998). Results from the DOK trial indicate that microbial cycling of P contributed more to plant-available P in biodynamic systems compared to conventional systems that receive synthetic fertilisers (Oehl *et al.* 2001 2004b). However, organic P mineralisation contributed only 10% of the inorganic P released into the soil solution and the higher P mineralisation rate in the biodynamic soils only partly compensated for its lower P availability (Oehl *et al.* 2004a). Other results from the DOK trial compared the biodynamic treatment with the conventional treatment that also received manure. Despite both treatments receiving the same quantity of manure, the biodynamic treatment had larger functional diversity (Fließbach *et al.* 2001), microbial C, incorporation of ^{14}C-labelled plant material into the microbial biomass and it mineralised 58% of the added C, compared to 50% in the conventional soil and unfertilised control (Fließbach *et al.* 2000, Mäder *et al.* 2002). However, differences between the treatments may have been as a result of the quality of the manure inputs or herbicide application in the conventional treatment decreasing microbial measurements by reducing weed populations (Fließbach *et al.* 2000). Previous studies have not supported the hypothesis that organic management alters soil function (Dann *et al.* 1996, Ryan and Ash 1999, Cookson *et al.* 2005a).

Results of field trials (Table 2.2) suggest that the effect of organic farming systems on physical fertility depend on the particular organic matter and tillage practices employed. The Washington State apple trial (Glover *et al.* 2000, Reganold *et al.* 2001) attributed lower bulk density in the organic treatment to the addition of compost and the use of tillage for weed control. However, tillage may have also reduced soil physical fertility in the organic treatment since aggregate stability was higher in the integrated treatment where compost was used without tillage. In the Roseworthy trial, the reduced physical fertility of the integrated treatment was attributed to tillage and stock trampling (Penfold *et al.* 1997). These differences among trials illustrate the importance of practices being matched to climate, soil types and production systems. In the DOK trial, the organic and conventional soils both received manure applications, had the same rotation and almost identical tillage practices. The treatments showed no difference in bulk density or the volume of total and large pores. The higher aggregate stability in organic treatment was assumed to correspond to lower soil erodibility, although measurements of splash erosion showed no difference (Siegrist *et al.* 1998). Lower rates of erosion were found on organic farms in paired comparisons (Lockeretz *et al.* 1981, Reganold *et al.* 1987) due to fewer tillage operations and the rotations used. In the Apelsvoll trial, soil erosion was reduced by presence of perennial grasses in the pasture phases of the forage systems, rather than by organic or conventional management (Eltun *et al.* 2002).

There were no measurable changes in plant available nutrients in the soil of the Apelsvoll trial, but N, P and K budgets were increasingly negative in the order of conventional > integrated > organic (Eltun *et al.* 2002). In this case, budgets may provide an early indicator of potential sustainability of the farming system. The two organic treatments had the lowest N leaching. The organic and biodynamic treatments of the Roseworthy trial showed declining levels of available P with only small inputs of P in the form of rock phosphate. The P budget for the biodynamic treatment was negative due to the removal of a hay crop (Penfold *et al.* 1995).

Soil quality indices have been used to compare the effect of organic and conventional farming systems on selected soil functions. In the Washington State apple trial, the lower soil quality rating for the conventional treatment (0.78, compared to 0.88 for the organic and 0.92 for the integrated treatments) was attributed to lack of organic matter inputs (Reganold *et al.* 2001). In the Apelsvoll trial (Eltun *et al.* 2002), the conventional treatments ranked higher than the organic treatments for the soil chemical and biological components of fertility assessed. Within each management system, the mixed farming systems had higher overall soil fertility than the arable rotations. However, for the soil function of minimising environmental impact, including nutrient runoff and soil erosion, the organic treatments rated higher than the conventional treatments (Eltun *et al.* 2002).

Compared to organic livestock treatments in field trials, organic arable rotations may have decreased mineralisable C and N as a result of the absence of manure applications (Wander *et al.* 1995), negative N budgets and greater reduction in soil N over time (Eltun *et al.* 2002). Results from the Apelsvoll trial indicated that mixed livestock–cropping systems may have higher inherent fertility than arable rotations (Breland and Eltun 1999) because of increased soil biological and physical fertility and lower N leaching (Eltun *et al.* 2002). However, the differences between livestock and arable rotations were reduced in organic systems because of the use of green and animal manures (Breland and Eltun 1999). These studies demonstrate the difficulty in making broad generalisations about soil conditions in organic farming systems without taking into account specific practices and local knowledge of soil and environmental conditions.

Conclusions

Organic farming systems have evolved globally on both chemical fertile and infertile soils, but national and international organic certification standards have originated primarily in regions with younger, chemically fertile soils. Whereas organic practices can improve soil physical and biological fertility, consistent effects are not always found, and soil chemical fertility may be reduced if inputs do not match those removed in produce, leading to mining of soil nutrients. The inability of organic farming practices to increase organic matter (and soil biological fertility) in some highly weathered soils and semi-arid environments could lead to unsustainable practices based on current certification standards. Simplistic adherence to national or international organic standards that deal with soil fertility will not automatically lead to sustainable organic farming systems without additional holistic management that takes into account all aspects of the farm environment, including climate, topography and soil type. Problems are most likely to occur if the soil is highly weathered and low in chemical fertility. This emphasises the need for local knowledge so that appropriate adjustments can be made in response to a decline in components of soil fertility. Adjustments might include changes in commodity and emphasis on long-term solutions that are preventative rather than reactive (Watson *et al.* 2002a). The extent to which organic farming practices that are used to improve soil fertility can be incorporated into conventional management systems may be a definitive factor in the development of more sustainable farming systems overall.

Emerging areas of research, such as the focus on 'soil priming', together with nanoscale approaches to soil processes, have the potential to allow more rigorous scientific investigation of aspects of organic farming that have been claimed based only on anecdotal evidence. Converging research in molecular microbiology, soil microbial diversity and increasing interest in soil ameliorants such as microbial cocktails, compost tea and relatively insoluble minerals has potential to provide evidence of complex processes of nutrient release in highly biologically active soils. Contributions to soil fertility from activated biological processes are likely to be minimised in soils that receive flushes of highly soluble nutrients as in conventional farming systems, but this may also occur where high quantities of manure or poorly composted organic matter are used. Furthermore, organic farming practices that merely mimic the emphasis on 'nutrient replacement' commonly used in conventional farming systems are unlikely to show the quantitative and qualitative changes in soil biological fertility necessary to make them sustainable.

Finally, the concept of 'sustainable yield' for a particular location may have greater potential to be explored in organic farming systems than in conventional systems. This is a complex question because in practice, production can be achieved even in the absence of soil (e.g. in hydroponics). Generally, chemical inputs into conventional agricultural systems are relatively unlimited (except by cost) and they can override potential contributions by some biological processes (Abbott and Murphy 2003). This is less likely in more nutrient-limited organic farming systems where the manipulation of nutrient cycling through management of soil organic matter has greater consequence. In this situation, the sustainability of the soil resource for defined conditions (commodity, management practice, climate and soil type) can be estimated without the possibility of 'overfertilisation' extending production to a level that might cause one or more forms of land degradation. It is not usual to consider productivity as being 'too high' in any farming system, but this could be the case when high levels of fertilisation or soil disturbance lead to nutrient loss through leaching or soil erosion. Management practices that establish a long-term balance among the three components of soil fertility are likely to be essential for calculating theoretical sustainable yield for any agricultural land use.

References

Abbott, L.K. and Murphy, D.V. 2003. What is soil biological fertility? In: Abbott L.K. and Murphy, D.V. (eds) *Soil Biological Fertility – A Key to Sustainable Land Use in Agriculture*. Kluwer Academic Publishers, the Netherlands. pp. 1–15.

AQIS 1998. *National Standard for Organic and Bio-dynamic Produce*. Australian Quarantine and Inspection Service (AQIS), Canberra.

Bakken, A.K., Gautneb, H. and Myhr, K. 1997. The potential of crushed rocks and mine tailings as slow-release K fertilisers assessed by intensive cropping with Italian ryegrass in different soil types. *Nutrient Cycling in Agroecosystems* 47: 41–48.

Bakken, A.K., Gautneb, H., Sveistrup, T. and Myhr, K. 2000. Crushed rocks and miner tailings applied as K fertilisers on grassland. *Nutrient Cycling in Agroecosystems* 56: 53–57.

Barker, W.W., Welch, S.A. and Banfield, J.F. 1997. Biogeochemical weathering of silicate minerals. In: Banfield, J.F. and Nealson, K.H. (eds) *Geomicrobiology: Interactions between Microbes and Minerals*. Mineralogical Society of America, Washington. pp. 391–428.

Barrow, N.J. 1985. Comparing the effectiveness of fertilisers. *Fertiliser Research* 8: 85–90.

Barrow, N.J., Malajczuk, N. and Shaw, T.C. 1977. A direct test of the ability of vesicular-arbuscular mycorrhiza to help plants take up fixed soil phosphate. *New Phytologist* 78: 269–276.

Berry, P.M., Sylvester-Bradley, R., Philipps, L., Hatch, D.J., Cuttle, S.P., Rayns, F.W. and Gosling, P. 2002. Is the productivity of organic farms restricted by the supply of available nitrogen? *Soil Use and Management* 18: 248–255.

Bloem, J., Lebbink, G., Zwart, K.B., Bouwman, L.A., Burgers, S.L.G.E., de Vos, J.A. and de Ruiter, P.C. 1994. Dynamics of microorganisms, microbivores and nitrogen mineralisation in winter wheat fields under conventional and integrated management. *Agriculture, Ecosystems and Environment* 51: 129–143.

Blum, W.E.H., Herbinger, B., Mentler, A., Ottner, F., Pollak, M., Unger, E. and Wenzel, W.W. 1989. The use of rock powders in agriculture. II. Efficiency of rock powders for soil amelioration. *Zeitschrift für Pflanzenernähung und Bodenkunde* 152: 427–430.

Bolland, M.D.A. and Baker, M.J. 2000. Powdered granite is not an effective fertilizer for clover and wheat in sandy soils from Western Australia. *Nutrient Cycling in Agroecosystems* 56: 59–68.

Bolton, H., Elliott, L.F., Papendick, R.I. and Bezdicek, D.F. 1985. Soil microbial biomass and selected soil enzyme activities: effect of fertilization and cropping practices. *Soil Biology and Biochemistry* 17: 297–302.

Bossio, D.A., Scow, K.M., Gunapala, N. and Graham, K.J. 1998. Determinants of soil microbial communities: effects of agricultural management, season, and soil type on phospholipid fatty acid profiles. *Microbial Ecology* 36: 1–12.

Breland, T.A. and Eltun, R. 1999. Soil microbial biomass and mineralization of carbon and nitrogen in ecological, integrated and conventional forage and arable cropping systems. *Biology and Fertility of Soils* 30: 193–201.

Chittendon, E.T., Stanton, D.J., Watson, J. and Hodgson, L. 1964. Serpentine and dunite as magnesium fertiliser. *New Zealand Journal of Agricultural Research* 10: 160–171.

Chittendon, E.T., Watson, J. and Hodgson, L. 1967. Magnesium uptake by pastures and apple leaves from top-dressings of ground serpentine and dunite. *New Zealand Journal of Agricultural Research* 7: 28–31.

Clarke, M.S., Horwarth, W.R., Shennan, C. and Scow, K.M. 1998. Changes in soil chemical properties resulting from organic and low-input farming practices. *Agronomy Journal* 90: 662–671.

Condron, L.M., Cameron, K.C., Di, H.J., Clough, T.J., Forbes, E.A., McLaren, R.G. and Silva, R.G. 2000. A comparison of soil and environmental quality under organic and conventional farming systems in New Zealand. *New Zealand Journal of Agricultural Research* 43: 443–466.

Cookson, W.R., Marschner, P., Abaye, D.A., Clark, I.M., Murphy, D.V., Stockdale, E.A. and Watson, C. 2005a. The influence of season, agricultural management and soil properties on gross nitrogen transformations and bacterial community structure. *Australian Journal of Soil Research* (in press).

Cookson, W.R., Marschner, P., Clark, I.M., Milton, N., Murphy, D.V., Osman, M., Stockdale, E.A. and Hirsch, P.R. 2005b. The influence of land use on the microbial community structure and functional response to soil temperature (5 and 25°C). *Microbial Ecology*. (in press).

Coroneos, C., Hinsinger, P. and Gilkes, R.J. 1996. Granite powder as a source of potassium for plants: a glasshouse bioassay comparing two pasture species. *Fertilizer Research* 45: 143–152.

Dann, P.R., Derrick, J.W., Dumaresq, D.C. and Ryan, M.H. 1996. The response of organic and conventionally grown wheat to superphosphate and reactive phosphate rock. *Australian Journal of Experimental Agriculture* 36: 71–78.

Degens, B.P. 1997. Macro-aggregation of soils by biological bonding and binding mechanisms and the factors affecting these: a review. *Australian Journal of Soil Research* 35: 431–459.

Deria, A.M., Bell, R.W. and O'Hara, G.W. 2003. Organic wheat production and soil nutrient status in a Mediterranean climatic zone. *Journal of Sustainable Agriculture* 21: 21–47.

Derrick, J.W. and Dumaresq, D.C. 1999. Soil chemical properties under organic and conventional management in southern New South Wales. *Australian Journal of Soil Research* 37: 1047–1055.

Doran, J.W., Sarrantonio, M. and Liebig, M.A. 1996. Soil health and sustainability. *Advances in Agronomy* 56: 1–54.

Drinkwater, L.E., Letourneau, D.K., Workneh, F., van Bruggen, A.H.C. and Shennan, C. 1995. Fundamental differences between conventional and organic tomato agroecosystems in California. *Ecological Application* 5: 1098–1112.

Drinkwater, L.E., Wagoner, P. and Sarrantonio, M. 1998. Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature* 396: 262–265.

Droogers, P. and Bouma, J. 1996. Biodynamic vs. conventional farming effects on soil structure expresses by simulated potential productivity. *Soil Science Society of America Journal* 60: 1552–1558.

Droogers, P, Fermont, A. and Bouma, J. 1996. Effects of ecological soil management on the workability and trafficability of a loamy soil in the Netherlands. *Geoderma* 73: 131–145.

Edmeades, D.C. 2002. The effects of liquid fertilisers derived from natural products on crop, pasture, and animal production: a review. *Australian Journal of Agricultural Research* 53(8): 965–976.

Eltun, R., Korsæth, A. and Nordheim, O. 2002. A comparison of environmental, soil fertility, yield, and economical effects in six cropping systems based on an eight year experiment in Norway. *Agriculture, Ecosystems and Environment* 90: 155–168.

Fillery, I.R.P. 2001. Fate of biologically fixed nitrogen in legume-based dryland farming systems: a review. *Australian Journal of Experimental Agriculture* 41: 361–381.

Fließbach, A. and Mäder, P. 2000. Microbial biomass and size density fractions differ between soils of organic and conventional agricultural systems. *Soil Biology and Biochemistry* 32: 757–768.

Fließbach, A., Mäder, P. and Niggli, U. 2000. Mineralisation and microbial assimilation of ^{14}C-labelled straw in soils of organic and conventional agricultural systems. *Soil Biology and Biochemistry* 32: 1131–1139.

Fließbach, A., Eyhorn, F., Mäder, P., Rentsch, D.I. and Hany, R. 2001. 'DOK' long-term farming systems trial: microbial biomass, activity and diversity affect the decomposition of plant residues. In: Rees, R.M., Ball, B.C., Campbell, C.D. and Watson, C.A. (eds) *Sustainable Management of Soil Organic Matter*. CABI Publishing, Wallingford. pp. 363–369.

Fortune, S., Conway, J.S., Philipps, L., Robinson, J.S., Stockdale, E.A. and Watson, C.A. 2001. N, P and K budgets for some UK organic farming systems – Implications for sustainability. In: Rees, R.M., Ball, B.C., Campbell, C.D. and Watson, C.A. (eds) *Sustainable Management of Soil Organic Matter*. CABI Publishing, Wallingford. pp. 286–293.

Fraser, D.G., Doran, J.W., Sahs, W.W. and Lesoing, G.W. 1988. Soil microbial populations and activities under conventional and organic management. *Journal of Environmental Quality* 17: 585–590.

Garcia–Gomez, A. Szmidt, R.A.K. and Roig, A. 2002. Enhancing of the composting rate of spent mushroom substrate by rock dust. *Compost Science and Utilization* 10: 99–104.

Gerhardt, R.-A. 1997. A comparative analysis of the effects of organic and conventional farming systems on soil structure. *Biological Agriculture and Horticulture* 14: 139–157.

Gillman, G.P. 1980. The effect of crushed basalt scoria on the cation exchange properties of a highly weathered soil. *Soil Science Society of America Journal* 44: 465–468.

Gillman, G.P., Burkett, D.C. and Coventry, R.J. 2001. A laboratory study of application of basalt dust to highly weathered soils: effect on soil cation chemistry. *Australian Journal of Soil Research* 39: 799–811.

Gillman, G.P., Burkett, D.C. and Coventry, R.J. 2002. Amending highly weathered soil with finely ground basalt rock. *Applied Geochemistry* 17: 987–1001.

Gil-Sotres, F., Trasar–Cepada, C., Leirós, M.C. and Seoane, S. 2005. Different approaches to evaluating soil quality using biochemical properties. *Soil Biology and Biochemistry* 37: 877–887.

Gleeson, D.B., Clipson, N., Melville, K., Gadd, G.M. and McDermott, F.P. 2005a. Characterization of fungal community structure on a weathered pegmatitic granite. *Microbial Ecology* (in press).

Gleeson, D.B., McDermott, F., Kennedy, N., Melville, K., Gadd, G.M. and Clipson, N. 2005b. Characterization of bacterial community structure on a weathered pegmatitic granite. *Microbial Ecology* (in press).

Glover, J.D., Reganold, J.P. and Andrews, P.K. 2000. Systematic method for rating soil quality of conventional, organic and integrated apple orchards in Washington State. *Agriculture, Ecosystem and Environment* 80: 29–45.

Gosling, P. and Shepherd, M. 2005. Long-term changes in soil fertility in organic arable farming systems in England, with particular reference to phosphorus and potassium. *Agriculture, Ecosystem and Environment* 105: 425–432.

Goulding, K.W.T., Murphy, D.V., MacDonald, A., Stockdale, E.A., Gaunt, J.L., Blake, L., Ayaga, G. and Brookes P. 2001. The role of soil organic matter and manures in sustainable nutrient cycling. In: Rees, R.M., Ball, B.C., Campbell, C.D. and Watson, C.A. (eds) *Sustainable Management of Soil Organic Matter*. CABI Publishing, Wallingford. pp. 221–232.

Gunapala, N. and Scow, K.M. 1998. Dynamics of soil microbial biomass and activity in conventional and organic farming systems. *Soil Biology and Biochemistry* 30: 805–816.

Gunapala, N., Venette, R.C., Feris, H. and Scow, K.M. 1998. Effects of soil management history on the rate of organic matter decomposition. *Soil Biology and Biochemistry* 30: 1917–1927.

Harley, A.D. and Gilkes, R.J. 2000. Factors influencing the release of plant nutrient elements from silicate rock powders: a geochemical overview. *Nutrient Cycling in Agroecosystems* 56: 11–36.

Hassink, J. 1997. The capacity of soils to preserve organic C and N by their association with clay and silt particles. *Plant and Soil* 191: 77–87.

Hauggaard–Nielsen, H., Ambus, P. and Jensen, E.S. 2003. The comparison of nitrogen use and leaching in sole cropped versus intercropped pea and barley. *Nutrient Cycling in Agroecosystems* 65: 289–300.

Hildebrand, E.E. and Schack–Kirchner, H. 2000. Initial effects of lime and rock powder application on soil solution chemistry in a dystric cambisol – results of model experiments. *Nutrient Cycling in Agroecosystems* 56: 69–78.

Hinsinger, P. 1998. How do plant roots acquire mineral nutrients? Chemical processes in the rhizosphere. *Advances in Agronomy* 64: 225–265.

Hinsinger, P. 2001. Bioavailability of soil inorganic P in the rhizosphere as affected by root–induced chemical changes: a review. *Plant and Soil* 237: 173–195.

Hinsinger, P. and Gilkes, R.J. 1997. Dissolution of phosphate roc in the rhizosphere of five plant species grown in an acid, P–fixing mineral substrate. *Geoderma* 75: 231–249.

Hinsinger, P., Bolland, M.D.A. and Gilkes, R.J. 1996. Silicate rock powder: effect on selected chemical properties of a range of soils from Western Australia and on plant growth as assessed in a glasshouse experiment. *Fertilizer Research* 45: 69–79.

Hinsinger, P., Barros, O.N.F., Benedetti, M.F., Noack, Y. and Callot, G. 2001. Plant-induced weathering of a basaltic rock: experimental evidence. *Geochimica et Cosmochimica Acta* 65: 137–152.

Hole, D.G., Perkins, A.J., Wilson, J.D., Alexander, I.H., Grice, P.V. and Evans, A.D. 2005. Does organic farming benefit biodiversity? *Biological Conservation* 122: 113–130.

Hughes, J.C. and Gilkes, R.J. 1994. Rock phosphate dissolution and bicarbonate–soluble P in some soils from south–western Australia. *Australian Journal of Soil Research* 32: 767–779.

Huston, M.A. 1993. Biological diversity, soils, and economics. *Science* 262: 1676–1680.

IFOAM 2002. *IFOAM Basic Standards for Organic Production and Processing.* International Federation of Organic Agriculture Movements, Tholey-Theley, Germany.

Jakobsen, I., Gazey, C. and Abbott, L.K. 2001. Phosphate transport by communities of arbuscular mycorrhizal fungi in soil cores from annual pastures. *New Phytologist* 149: 93–103.

Jordahl, J.K. and Karlen, D.L. 1993. Comparison of alternative farming systems. III. Soil aggregate stability. *American Journal of Alternative Agriculture* 8: 27–33.

Kahnt, G., Pfleiderer, H. and Hijazi, L.A. 1986. Effect of amelioration dosed of rock powder and rock sand on growth of agricultural plants and on physical characteristics of sandy and clay soil. *Agronomy and Crop Science* 157: 169–180.

Kanobo, I.A.K. and Gilkes, R.J. 1987. The role of soil pH in the dissolution of phosphate rock fertilizers. *Fertilizer Research* 12: 165–174.

Kanobo, I.A.K. and Gilkes, R.J. 1988. The effect of particle size in North Carolina phosphate rock on it dissolution in soil and on levels of bicarbonate-soluble phosphorus. *Fertilizer Research* 15: 137–145.

Khasawneh, F.E. and Doll, E.C. 1978. The use of phosphate rock for direct application to soils. *Advances in Agronomy* 30: 159–206.

Kirchmann, H. 1994. Biological dynamic agriculture – an occult form of agriculture? *Journal of Agricultural and Environmental Ethics* 7: 173–187.

Kirchmann, H. and Bergström, L. 2001. Do organic farming systems reduce nitrate leaching? *Communications in Soil Science and Plant Analysis* 32: 997–1028.

Kirchmann, H. and Ryan, M.H. 2004. Nutrients in organic farming – are there advantages from the exclusive use of organic manures and untreated minerals? In: Fischer, T., Turner, N., Angus, J., McIntyre, L., Robertson, M., Borrell, A. and Lloyd, D. (eds) *New directions for a diverse planet. Proceedings of the 4th International Crop Science Congress*. 26 Sept–1 Oct. 2004, Brisbane, Australia. The Regional Institute, Gosford.

Kirchmann, H. and Thorvaldsson, G. 2000. Challenging targets for future agriculture. *European Journal of Agronomy* 12: 145–161.

Korsæth, A. and Eltun, R. 2000. Nitrogen mass balances in conventional, integrated and ecological cropping systems and the relationship between balance calculations and nitrogen run off in an eight-year field experiment in Norway. *Agriculture, Ecosystems and Environment* 79: 199–214.

Kristensen, L., Stopes, C., Kolster, P. and Granstedt, A. 1995. Nitrogen leaching in ecological agriculture: summary and recommendations. In: *Nitrogen Leaching in Ecological Agriculture*. A.B. Academic Publishers, Great Britain. pp. 331–340.

Lampkin, N. 1990. *Organic Farming.* Farming Press Books, Ipswich.

Lee, K.E. and Pankhurst, C.E. 1992. Soil organisms and sustainable productivity. *Australian Journal of Soil Research* 30: 855–892.

Le Guillou, G. and Scharpé, A. 2000. *Organic Farming – Guide to Community Rules.* European Community, Brussels.

Léon, L.A., Fenster, W.E. and Hammond, L.L. 1986. Agronomic potential of eleven phosphate rocks from Brazil, Colombia, Peru, and Venezuela. *Soil Science Society of America Journal* 50: 798–802.

Leonardos, O.H., Fyfe, W.S. and Kronberg, B.I. 1987. The use of ground rocks in laterite systems: an improvement to the use of conventional soluble fertilizers? *Chemical Geology* 60: 361–370.

Leonardos, O.H., Theodoro, S.H. and Assad, M.L. 2000. Remineralization for sustainable agriculture: a tropical perspective from a Brazilian viewpoint. *Nutrient Cycling in Agroecosystems* 56: 3–9.

Liebig, M.A. and Doran, J.W. 1999. Impact of organic production practices on soil quality indicators. *Journal of Environmental Quality* 28: 1601–1609.

Lim, H.H., Gilkes, R.J. and McCormick, P.G. 2003. Benefication of rock phosphate fertilisers by mechano-milling. *Nutrient Cycling in Agroecosystems* 67: 177–186.

Lockeretz, W., Shearer, G. and Kohl, D. 1981. Organic farming in the corn belt. *Science* 211: 540–547.

Lytton–Hitchins, J.A., Koppi, A.J. and McBratney, AB. 1994. The soil condition of adjacent bio-dynamic and conventionally managed dairy pastures in Victoria, Australia. *Soil, Use and Management* 10: 79–87.

Mäder, P., Edenhofer, S., Boller, T., Wiemken, A. and Niggli, U. 2000. Arbuscular mycorrhizae in a long-term field trial comparing low-input (organic, biological) and high-input (conventional) farming systems in a crop rotation. *Biology and Fertility of Soils* 31: 150–156.

Mäder, P., Fließbach, A., Dubois, D., Gunst, L., Fried, P. and Niggli, U. 2002. Soil fertility and biodiversity in organic farming. *Science* 296: 1694–1697.

Marschner, P. and Rengel, Z. 2003. Contributions of rhizosphere interactions to soil biological fertility. In: Abbott, L.K. and Murphy, D.V. (eds) *Soil Biological Fertility – A Key to Sustainable Land Use in Agriculture*. Kluwer Academic Publishers, the Netherlands. pp. 81–98.

Murata, T. and Goh, K.M. 1997. Effects of cropping systems on soil organic matter in a pair of conventional and biodynamic mixed crop farms in Canterbury, New Zealand. *Biology and Fertility of Soils* 25: 372–381.

NASAA 2003. *The Standards for Organic Agricultural Production*. National Association for Sustainable Agriculture Australia, Stirling.

Nguyen, M.L., Haynes, R.J. and Goh, K.M. 1995. Nutrient budgets and status in three pairs of conventional and alternative mixed cropping farms in Canterbury, New Zealand. *Agriculture, Ecosystem and Environment* 52: 149–162.

Niwas, J.M. and Dissanayake, C.B. 1987. Rocks as fertilizers: preliminary studies on potassium availability of some common rocks of Sri Lanka. *Applied Geochemistry* 2: 243–246.

Nortcliff, S. 2002. Standardisation of soil quality attributes. *Agriculture, Ecosystem and Environment* 88: 161–168.

Oberson, A., Fardeau, J.C., Besson, J.M. and Sticher, H. 1993. Soil phosphorus dynamics in cropping systems managed according to conventional and biological agricultural methods. *Biology and Fertility of Soils* 16: 111–117.

Öborn, I., Edwards, A.C., Witter, E., Oenema, O., Ivarsson, K., Withers, P.J.A., Nilsson, S.I. and Richert Stinzing, A. 2003. Element balances as a tool for sustainable nutrient management: a critical appraisal of their merits and limitations within an agronomic and environmental context. *European Journal of Agronomy* 20: 211–225.

Oehl, F., Oberson, A., Probst, M., Fließbach, A., Roth, H. and Frossard, E. 2001. Kinetics of microbial phosphorus uptake in cultivated soils. *Biology and Fertility of Soils* 34: 31–41.

Oehl, F., Oberson, A., Tagmann, H.U., Besson, J.M., Dubois, D., Roth, H. and Frossard, E. 2002. Phosphorus budget and phosphorus availability in soils under organic and conventional farming. *Nutrient Cycling in Agroecosystems* 62: 25–35.

Oehl, F., Frossard, E., Fließbach, A., Dubois, D. and Oberson, A. 2004a. Basal organic phosphorus mineralization in soils under different farming systems. *Soil Biology and Biochemistry* 36: 667–675.

Oehl, F., Sieverding, E., Mäder, P., Dubois, D., Ineichen, K., Boller, T. and Wiemken, A. 2004b. Impact of long-term conventional and organic farming on the diversity of arbuscular mycorrhizal fungi. *Oecologia* 138: 574–583.

Oenema, O., Kros, H. and de Vries, W. 2003. Approaches and uncertainties in nutrient budgets: implications for nutrient management and environmental policies. *European Journal of Agronomy* 20: 3–16.

Osler, G.H.R., Recous, S., Fillery, I.R.P., Gauci, C.S., Zhu C. and Abbott, L.K. 2004. Correlation between mite community structure and gross N fluxes. *Soil Biology and Biochemistry* 36: 191–194.

Pairunan, A.K., Robson, A.D. and Abbott, L.K. 1980. The effectiveness of vesicular–arbuscular mycorrhizas in increasing growth and phosphorus uptake of subterranean clover from phosphorus sources of different solubilities. *New Phytologist* 84: 327–338.

Parr, J.F., Papendick, R.I. and Youngberg, I.G. 1983. Organic farming in the United States: principles and perspective. *Agro-Ecosystems* 8: 183–201.

Penfold, C. 1997. *Biological Farming Systems – Unravelling the Mysteries.* Rural Industries Research and Development Corporation, Canberra.

Penfold, C.M., Miyan, M.S., Reeves, T.G. and Grierson, I.T. 1995. Biological farming for sustainable agricultural production. *Australian Journal of Experimental Agriculture* 35: 849–856.

Price, G.H. 2001. New horizons in soil fertility management. *Australian Journal of Soil Research* 39: 683–710.

Priyono, J. and Gilkes, R.J. 2004. Dissolution of milled-silicate rock fertilisers in the soil. *Australian Journal of Soil Research* 42: 441–448.

Puckridge, D.W. and French, R.J. 1983. The annual legume pasture in cereal–ley farming systems of southern Australia: a review. *Agriculture, Ecosystems and Environment* 9: 229–267.

Reganold, J.P., Elliot, L.F. and Unger, Y.L. 1987. Long-term effects of organic and conventional farming on soil erosion. *Nature* 330: 370–372.

Reganold, J.P., Papendick, R.I. and Parr, J.F. 1990. Sustainable agriculture. *Scientific American* 262: 112–120.

Reganold, J.P., Palmer, A.S., Lockhart, J.C. and Macgregor, A.N. 1993. Soil quality and financial performance of biodynamic and conventional farms in New Zealand. *Science* 260: 344–349.

Reganold, J.P., Glover, J.D., Andrews, P.K. and Hinman, H.R. 2001. Sustainability of three production systems. *Nature* 410: 926–930.

Richardson, A.E. 2001. Prospects for using soil microorganisms to improve the acquisition of phosphorus by plants. *Australian Journal of Plant Physiology* 28: 897–906.

Ridley, E.M., Mele, P.M. and Beverly, C.R. 2004. Legume-based farming in Southern Australia: developing sustainable systems to meet environmental challenges. *Soil Biology and Biochemistry* 36: 1213–1221.

Robertson, F.A. and Morgan, W.C. 1996. Effects of management history and legume green manure on soil microorganisms under 'organic' vegetable production. *Australian Journal of Soil Research* 34: 427–440.

Rogers, J.R. and Bennett, P.C. 2004. Mineral stimulation of subsurface microorganisms: release of limiting nutrients from silicates. *Chemical Geology* 203: 91–108.

Ryan, M. 1999. Is an enhanced soil biological community, relative to conventional neighbours, a consistent feature of alternative (organic and biodynamic) agricultural systems? *Biological Agriculture and Horticulture* 17: 131–144.

Ryan, M.H and Angus, J.F. 2003. Arbuscular mycorrhizae in wheat and field pea crops on a low P soil: increased Zn-uptake but no increase in P-uptake or yield. *Plant and Soil* 250: 225–239.

Ryan, M.H. and Ash, J. 1999. Effects of phosphorus and nitrogen on growth of pasture plants and AM fungi in SE Australian soils with contrasting fertiliser histories (conventional and biodynamic). *Agriculture Ecosystems and Environment* 73: 51–62.

Ryan, M.H. and Graham, J.H. 2002. Is there a role for arbuscular mycorrhizal fungi in production agriculture? *Plant and Soil* 244: 263–271.

Ryan, M.H., Chilvers, G.A., Dumaresq, D.C. 1994. Colonisation of wheat by VA–mycorrhizal fungi was found to be higher on a farm managed in an organic manner than on a conventional neighbour. *Plant and Soil* 160: 33–40.

Ryan, M.H., Small, D.R. and Ash, J.E. 2000. Phosphorus controls the level of colonisation by arbuscular mycorrhizal fungi in conventional and biodynamic irrigated dairy pastures. *Australian Journal of Experimental Agriculture* 40: 663–670.

Sans Scovino, J.I. and Rowell, D.L. 1988. The use of feldspars as potassium fertilizers in the savannah of Colombia. *Fertilizer Research* 17: 71–83.

Schweiger, P. 1993. *Factors affecting VA mycorrhizal uptake of phosphorus*. PhD thesis, University of Western Australia, Nedlands.

Shepherd, M.A., Harrison, R. and Webb, J. 2002. Managing soil organic matter – implications for soil structure on organic farms. *Soil Use and Management* 18: 284–292.

Siegrist, S., Schaub, D., Piffner, N. and Mäder, P. 1998. Does organic agriculture reduce soil erodibility? The results of a long–term field trial on loess in Switzerland. *Agriculture, Ecosystems and Environment* 69: 253–264.

Smith, S.E., Robson, A.D. and Abbott, L.K. 1992. The involvement of mycorrhizas in genetically-dependent efficiency of nutrient uptake and use. *Plant and Soil* 146: 169–179.

Steen Jensen, E. and Hauggaard-Nielsen, H. 2003. How can increased use of biological N_2 fixation in agriculture benefit the environment? *Plant and Soil* 252: 177–186.

Stockdale, E.A. and Cookson, W.R. 2003. Sustainable farming systems and their impact on soil biological fertility – some case studies. In: Abbott L.K. and Murphy, D.V. (eds) *Soil Biological Fertility – A Key to Sustainable Land Use in Agriculture*. Kluwer Academic Publishers, The Netherlands. pp. 225–239.

Stockdale, E.A., Lampkin, N.H., Hovi, M., Keatinge, R., Lennartsson, E.K.M., Macdonald, D.W., Padel, S. 2001. Agronomic and environmental implications of organic farming systems. *Advances in Agronomy* 70: 261–327.

Stockdale, E.A., Shepherd, M.A., Fortune, S. and Cuttle, S.P. 2002. Soil fertility in organic farming systems – fundamentally different? *Soil Use and Management* 18: 301–308.

Stork, P.R. and Jerie, P.H. 2003. Initial studies of the growth, nitrogen sequestering, and dewatering potential of perennial grass selections for use as nitrogen catch crops in orchards. *Australian Journal of Agricultural Research* 54: 27–37.

Strong, D.T., Sale, P.W.G. and Helyar, K.R. 1999. The influence of the soil matrix on nitrogen mineralisation and nitrification. IV. Texture. *Australian Journal of Soil Research* 37: 329–344.

Thompson, J.P. 1987. Decline of vesicular–arbuscular mycorrhizae in long fallow disorder of field crops and its expression in phosphorus deficiency of sunflower. *Australian Journal of Agricultural Research* 38: 847–867.

Thompson, J.P. 1990. Soil sterilization methods to show VA–mycorrhizae aid P and Zn nutrition of wheat in vertisols. *Soil Biology and Biochemistry* 22: 229–240.

Thorup-Kristensen, K. 2001. Are differences in root growth of nitrogen catch crops important for their ability to reduce soil nitrate-N content, and how can this be measured? *Plant and Soil* 230: 185–195.

Treadwell, D.D., McKinney, D.E. and Creamer, N.G. 2003. From philosophy to science: a brief history of organic horticulture in the United States. *Hortscience* 35: 1009–1014.

Verkleij, F.N. 1992. Seaweed extracts in agriculture and horticulture: a review. *Biological Agriculture and Horticulture* 8: 309–324.

von Fragstein, P. and Vogtmann, H. 1983. Organic extracts for the treatment of rock powder fertilizers in biological agriculture. *Biological Agriculture and Horticulture* 1: 169–180.

von Fragstein, P., Pertl, W. and Vogtmann, H. 1988. Artificial weathering of silicate rock powders. *Zeitschrift für Pflanzenernähung und Bodenkunde* 151: 141–146.

von Mersi, W., Kuhnert-Finkernagel, R. and Schinner, F. 1992. The influence of rock powders in microbial activity of three forest soils. *Zeitschrift für Pflanzenernähung und Bodenkunde* 155: 29–33.

Wander, M.M., Hedrick, D.S., Kaufman, D., Traina, S.J., Stinner, B.R., Kehrmayer, S.R. and White, D.C. 1995. The functional significance of the microbial in organic and conventionally managed soils. *Plant and Soil* 170: 87–97.

Wang, J.S., Zhang, F.S., Cao, Y.P. and Zhang, X.L. 2000. Effect of plant types on release of mineral potassium from gneiss. *Nutrient Cycling in Agroecosystems* 56: 37–44.

Watson, C.A., Atkinson, D., Gosling, P., Jackson, LR. and Rayns, F.W. 2002a. Managing soil fertility in organic farming systems. *Soil Use and Management* 18: 239–247.

Watson, C.A., Bengtsson, H., Ebbesvik, M., Løes, A.-K., Myrbeck, A., Salomon, E., Schroder, J. and Stockdale, E.A. 2002b. A review of farm-scale nutrient budgets for organic farms as a tool for management of soil fertility. *Soil Use and Management* 18: 264–273.

Watts, C.W., Whalley, W.R., Longstaff, D.J., White, R.P., Brooke, P.C and Whitmore, A.P. 2001. Aggregation of a soil with different cropping histories following the addition of organic materials. *Soil Use and Management* 17: 263–268.

Welbaum, G.E., Sturtz, A.V., Dong, Z. and Nowak, J. 2004. Managing soil microorganisms to improve productivity of agro-ecosystems. *Critical Reviews in Plant Sciences* 23: 175–193.

Wells, A.T., Chan, K.Y. and Cornish, P.S. 2000. Comparison of conventional and alternative vegetable farming systems on the properties of a yellow earth in New South Wales. *Agriculture, Ecosystem and Environment* 80: 47–60.

Werner, M.R. 1997. Soil quality characteristics during conversion to organic orchard management. *Applied Soil Ecology* 5: 151–167.

Yeates, G.W., Bardgett, R.D., Cook, R., Hobbs, P.J., Bowling, P.J. and Potter, J.F. 1997. Faunal and microbial diversity in three Welsh grassland soils under conventional and organic management regimes. *Journal of Applied Ecology* 34: 453–470.

Chapter 3

Crop agronomy in organic agriculture

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Introduction

Organic crop husbandry is based on practices outlined in the various organic standards that have been developed and documented in many countries. The most widely recognised organic standards are those published by the International Federation of Organic Agriculture Movements (IFOAM 2002). Organic farming methods emphasise the use of internal on-farm inputs rather than externally sourced inputs to achieve essential soil fertility, nutrient management and plant protection goals. Self-regulation within an agroecosystem, multi-year management cycles and a focus on prevention rather than reaction, are key principles in organic farming that underpin organic plant production.

The core element in organic crop husbandry is the management of a site-specific and market-oriented *crop rotation*. Alternating a wide range of crops over time and space can facilitate efficient use of the soil resource of a farm by cultivating crops of varying profiles in nutrient demand and supply, growth habit and phytosanitary characteristics. As the specialisation in stockless farming expands regionally and globally, the importance of crop rotations in nutrient management increases and there is greater reliance on off-farm sources of manures. While the trend towards stockless systems may raise questions about sustainability in some areas, the more crop husbandry is market-oriented or commercially driven, the more conflicts are likely to arise as good organic agricultural practices are compromised. For example, the need to forego sufficient soil fertility building components in a rotation, whether with livestock or legumes, in favour of more components as cash crops.

In addition to crop rotations, a range of other *cultural strategies* used in organic farming to achieve various farm management objectives are discussed in this chapter. Organic agriculture is an integral part of broader landscape management. Even small-scale farming can contribute to increase and enhance the proportion of non-productive area of a holding. In some cases, especially on leased farms, the establishment of perennial components such as hedges, tree lots or ponds is difficult to implement. As an alternative, flowering field margins or corridors can be integrated as an annual enrichment of the agroecosystem, increasing the abundance of faunal elements for better self-regulation among adjacent fields. The main focus of this chapter is mixed and stockless annual cropping systems, rather than purely perennial farming systems such as tree and vine crops.

The success of organic crop husbandry also relies very much on effective *weed management*, although diverging views can be found regarding the necessity of 'clean' crops versus the approach of higher agrobiodiversity through more natural, wild flora components in a field. Weeds are widely reported as a major constraint in organic production and severe crop losses can be experienced, particularly during conversion and in phase changes in rotations (e.g. from pasture to arable cropping). A review of plant pest and diseases in organic farming is presented in the following chapter.

While many important generalisations can be made about soil processes, plant growth and so on, the performance of particular farming systems, cropping rotations and crop varieties will always be determined by the local conditions. Historically, most of the research into organic farming has been conducted in western Europe, the home of modern organic agriculture. However, when the environmental and market conditions are different to those experienced in western Europe, organic farmers need to be innovative and incorporate local knowledge (e.g. Augstburger *et al.* 2002, Jambhekar 2003).

Crop rotations

The central role of crop rotations in organic farming is highlighted by the important focus on rotations in many organics certification standards. For example, in the United Kingdom (UK), the standards for plant production (including pastures) require a 'multi-annual rotation programme' for building soil fertility and managing weeds, pests and diseases (Advisory Committee on Organic Standards 2004). Wijnands (1999) provided a description what a crop rotation means and how it should be implemented on an organic farm:

> Crop rotation is the term used to [indicate] that crops are grown over time in a very specific order. After a number of years (length of the crop rotation), the cycle will be repeated. The crops grown in one year on the available area of a farm make up the cropping plan. If the crop rotation is consistent and unchanged, the cropping plan is the same every year. Crop rotation has a temporal aspect [where] crops are grown over time in a specific order (succession of crops in time); and a spatial aspect [where] the crops grown this year and their division over the available space. The interaction between spatial and temporal aspects can be used to strengthen the crop rotation concept. Rotating the crops on the available space is done so that a given crop is never grown next to a field with the same preceding crop (spatial crop rotation). This helps to prevent semi-mobile pests and diseases from surviving from one year to the next.

The aims of crop rotations in organic farming systems were summarised by Kahnt *et al.* (1997):

- maintenance and improvement of soil fertility
- maintenance and improvement of soil organic matter
- maximisation of symbiotic N fixation through cultivation of forage and grain legumes
- production of sufficient food and straw for animal husbandry
- optimised use of pre-crop effect through crops with high gross margin
- mobilisation of nutrients through crops with high root density and root depth
- control and reduction of pests and diseases
- control of weed competition combined with gentle soil cultivation
- improvement of time management for crop husbandry-specific labour
- maintenance and improvement of the economic situation of the farm.

In mixed farms, the crop rotation is mainly focused to provide enough fodder for the different animal species. Therefore, the rotational plan will react to market demands only to a limited extent. This can be contrasted with farms with little or no livestock, in which case commercially desirable crops may dominate the crop rotation (Bulson *et al.* 1996). From the production point of view, the rotational system has to meet requirements for the maintenance of soil fertility, nutrient supply and control of weeds, pests and diseases (Robson *et al.* 2002). Economic aspects also influence decisions about crop rotations, such as labour management and maintaining the continuity of farm cash flow through fluctuating market and circumstances (Smith *et al.* 2004b). In organic farming, the tension between short-term (economic) demands and long-term (ecological) needs creates challenges for farmers, and complex skills are required to balance the competing interests by managing a sequence of crops that provide direct cash benefits as well as indirect ecological services (e.g. Sandhu *et al.* 2005).

Nutrient management

The structure of organic rotations generally consists of two parts. First, legumes are used as a soil fertility-increasing component, from yearly to multi-year crops, mainly in the form of forage legumes, with much less in the form of grain legumes (Herrmann and Plakolm 1991) and, second, periods with non-legumes such as cereals, root crops or field vegetables, relying on the accumulation of humus, organic nitrogen (N) and depleting the resources.

In organic farming, the emphasis is on developing healthy, biologically active soil through the use of certified inputs and land management practices. Inputs used in rotations include plant residues, animal manures, rock dusts and biological activators (IFOAM 2002). Additionally, biological activity is promoted so that soil processes such as nutrient cycling and soil structural development are facilitated (Schjønning *et al.* 2002, Shepherd *et al.* 2002). Crop and pasture plants then rely on the mineral nutrients that are made available in the soil. Stockdale *et al.* (2002) have indicated that the underlying soil processes and nutrient pools are similar in organic and conventional soils although the relative rates and importance of individual processes differ between farming systems. While many soil changes under organic management may be clearly significant, other research shows that changes are often 'subtle rather than dramatic' (Shannon *et al.* 2002) (see Chapter 2 for a review of soil fertility).

Careful N management is needed for most crops in order to maximise yields while minimising nutrient leakage. In organic farming, this mobile nutrient is usually not difficult to supply, whether through legumes or animal manures, but is easily lost from the system (van Delden *et al.* 2003). Phosphorus (P) is a very immobile nutrient, especially at higher pH levels, and organically certified sources of P commonly have low solubility (Oehl *et al.* 2002). As a consequence, several recent studies have highlighted the lack of sustainability in existing organic P management in different settings (Gosling and Shepherd 2005). Using farm-scale nutrient budgets, Watson *et al.* (2002) confirmed that N was generally not a problem but that P and K were being depleted in some systems, particularly arable cropping (Figure 3.1). Dairy farms had low nutrient budgets as a result of the very low reliance on external inputs, while horticultural farms had noticeably high budgets, presumably as a result of large externally sourced inputs of manure. The longer-term decline of P soil reserves in some organic farms in Germany has been highlighted by Lampkin (1990), where the older organic farms have less P than newer organic farms (Figure 3.2), a trend not observed in paired conventional farms.

By including greater carbon (C) inputs in the soil, organic producers are able to store nitrogen and other nutrients for future crop use, while minimising the risk of environmental pollution (Poudel *et al.* 2001). Indeed, Shepherd *et al.* (2002) asserted that improved soil structure was dependant on frequent, and presumably large, inputs of fresh organic matter, a common practice in organic agriculture. Edmeades' (2003) review of several conventional field trials comparing the long-term (20–120 years) effects of fertilisers and manures (farmyard

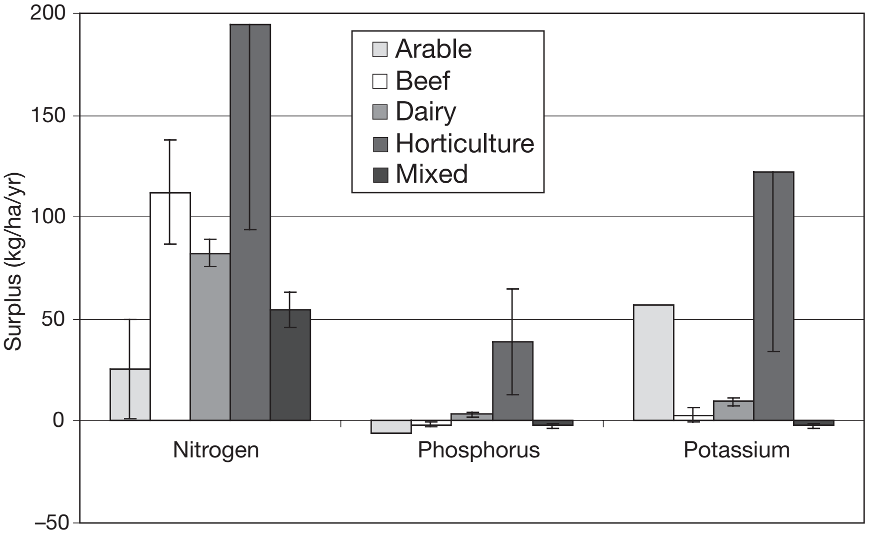

Figure 3.1 Average farm-scale nutrient budget surpluses (average input minus output) for nitrogen, phosphorus and potassium on various organic farm types in temperate countries (after Watson *et al.* 2002).

manure, slurry and green manure) on crop production and soil properties indicated that large amounts of manures and other organic inputs were needed to get improved soil chemical and physical properties, but crop yield was not affected.

Green manures

The cultivation of crops that are not devoted to selling or feeding purposes is commonly understood as green manuring. Older definitions focused more on the fertilising aspects that were achieved by incorporation of crops in an immature stage. More recent understandings

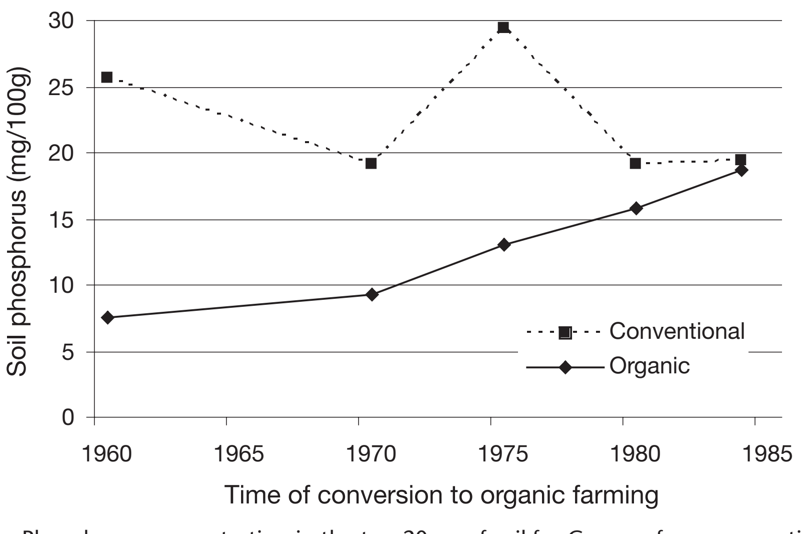

Figure 3.2 Phosphorus concentration in the top 20cm of soil for German farms converting to organic practices in the years from before 1960 to 1984 compared with paired conventional farms (after Lampkin 1990).

emphasise a variety of pre-crop effects including soil physical, chemical and biological aspects, as well as ecological services such as crop protection and weed control. Green manuring in a rotation contributes to a higher level of biodiversity in time and space.

Depending on the period and the purpose of cultivation, there is a distinction between green manure as *main crop*, *intermediate crop* and *companion crop*. Terms such as catch crop or cover crop are synonymous with *intermediate crop*. The first term clearly indicates the expectations for N-conserving activities in the crops used, mainly fast-growing crucifers and grass species. The second term is similar, but also emphasises the soil conservation action of covering the soil with vegetation. Undersowing or, more recently introduced, living mulch systems increase the complexity of a growing system by combining different partners at the same time (Paine and Harrison 1993). Often, such an approach in planting design is also named the intercropping system, a concept that was commonly applied in traditional farming systems throughout the world. It now covers a wide range of techniques such as undersowing, dual cropping, strip cropping and even agroforestry, hedging, shelterbelts and windbreaks. All of these methods involve increased plant diversification within a farm and can result in increased opportunities for agroecological processes to occur (Altieri and Letourneau 1982). The potential benefits of intercropping include improvements in soil fertility, resource capture, pest and disease control, weed management and risk management. However, intercropping requires good farm management skills to satisfy the full agronomic needs of more than one crop. Useful introductions to the intercropping concept and assessment are Francis (1986), Vandermeer (1989) and more recently, Theunissen (1997).

Intercropping systems using *in situ* mulch crops have been widely tested, particularly in the United States of America (USA) (Abdul-Baki and Teasdale 1993, Creamer *et al.* 1996, Hutchinson and McGiffen 2000). Using leguminous cover crops in cabbage, Brandsæter and Riley (2002) found soil fertility and weed control benefits but also noted that interspecific competition was a major problem. Careful matching of secondary crops with the primary crop and the prevailing growing conditions is needed based on relative vigour, timing of growth phases and complementarity of resource use. Intercropping may be especially suitable for row crops with poor competitiveness against weeds.

Perennial farming systems with tree, bush or vine crops also provide niches for short and longer term intercropping. In addition to the use of cover crops on the orchard floor of many crops including apples (Hartley *et al.* 2000) and wine grapes (Bugg *et al.* 1996), plantings of commercially and environmentally valuable species within or around the orchard have also been used for pollination, disease and pest control (Finckh and Wolfe 1998, Altieri 1999) in crops such as such as leeks (Baumann *et al.* 2001) and carrots (Brandsæter and Riley 2002).

Within the European Union (EU), specific programs facilitate the use of one-year set-aside crop mixtures. This is often managed within a biennial or longer grass clover crop, out of which one year is financed by subsidies and not fed to animals. Similar effects, although on a lower level, can be expected from a one-year forage crop by excluding the last cut as roughage and providing additional biomass as C and organic N supplied to the soil (Heß 1993). The one-year green manuring is most valuable as a humus source, whereas the quickly degraded biomass of green manure provides more nutrients and energy sources for soil organisms and improves the fertility for the subsequent crop (Schonbeck *et al.* 1993).

Forage legumes were found to be more efficient in supplying N to subsequent wheat (*Triticum aestivum*) crops than grain legumes such as pea (*Pisum* spp.) or vetch (*Vicia* spp.) (Evans *et al.* 2003). Similar N conserving effects of different cover crops have been described by Fowler *et al.* (2004) and Haas (2004) in regard to organic farms in New Zealand and Germany respectively. The improvement in soil structure by the root residues of the preceding forage legumes was more important for the performance of a succeeding lettuce (*Lactuca sativa*) crop than the impact of the N supply alone (Wivstad *et al.* 2003).

Table 3.1 Types of crop rotations (Freyer 2003)
F, forage legumes; G, grain legumes; N, non-legumes; C, cover crops; U, undersowings.

No. of fields	Year							F%	G%	C, U%
	1	2	3	4	5	6	7			
4	F	N	N+C	N+U				25	0	50
	F	N	G	N+U				25	25	25
	F	F	N	N+U				50	0	25
5	F	N	N+C	G	N+U			20	20	40
	F	F	N	N+C	N+U			40	0	40
	F	F	N+U	N+C	N+U			40	0	60
6	F	F	N	N+C	N+C	N+U		33	0	50
	F	F	N	N+C	G	N+U		33	17	33
	F	F	F	N	N	N+U		50	0	17
7	F	N	N+C	N+C	N	G	N+U	15	15	42
	F	F	N	N+C	N+C	N	N+U	28	0	42
	F	F	N	N+C	N+C	N+C	N+U	28	0	57
	F	F	F	N	N	N+C	N+U	42	0	28

Allelopathic properties of glucosinolate-containing crucifers are highly relevant for their phytosanitary effects ('biofumigation') against the incidence of soilborne diseases (Lazzari and Manici 2001, Smith *et al.* 2004a). Buckwheat as green manure may act similarly against various weeds as a result of the presence of gallic acid (Iqbal *et al.* 2003). Infestations by root-knot nematodes, a severe pest in vegetable cultivation, can be reduced by various green manures such as radish (Nucifora *et al.* 1998), marigold and sudangrass (Abawi and Vogel 2000). Living mulches can be very effective against various pests as a result of increased predator occurrence or increased disorientation of herbivores (Hooks *et al.* 1998).

Whereas Wijnands (1999) reported very limited use of green manure crops as part of crop rotations in Dutch organic farms (3 of 68 interviewed farmers), German surveys in organic agricultural (Rahmann *et al.* 2004) and vegetable holdings (Fragstein *et al.* 2004) revealed that 60% of arable farms and 63% of vegetable farms used cover crops or undersowing. In a survey of organic farmers in the USA, the most common (72%) soil fertility management practice reported was the use of cover crops (Walz 1999).

Designing rotations

Freyer (2003) developed a range of rotations that differ in length and structure, specifically the proportion of forage legumes, grain legumes and cover or undersown crops (Table 3.1). The grain legumes should not exceed a proportion of 33%. Forage legumes, if cultivated in mixtures of clover and/or alfalfa and grass species, can achieve mixtures up to 50%. Because of incompatibilities, soilborne diseases and other factors, higher proportions of legumes can cause serious yield losses in a long-term perspective of rotations (Table 3.2).

The increase of species biodiversity in organic farming is exemplified by the range of potential cover crops and undersowings used in the rotations. Under favourable conditions forage legumes can be integrated into the rotation as undersowing in the preceding cereals. If the performance of the undersowing crop is poor, it should be replaced by a stubble crop sown after cereal harvest. However, the one or multi-year forage legume-part of the rotation is too important for the overall success of the rotation (e.g. for N fixation and other tasks) to be able to accept a 'poor' performance. Cover crops may be best suited when winter crops are substituted

Table 3.2 Interval of crops due to incompatibilities or biotic factors (Müller 1988)

Crop	Year	Incompatibility	Viruses	Fungi	Nematodes	Insects
Winter wheat	2			✓	✓	
Winter barley	1–2			✓		✓
Spring barley	0–1				✓	
Oats	3–5				✓	
Winter rye	0–1			✓		
Potatoes	3–4				✓	
Sugar beet	4			✓	✓	
Rape	3			✓	✓	
Field peas	4	✓		✓		
Flax	6	✓		✓		
Faba beans, lupins	3	✓	✓	✓		
Lucerne	4–5	✓		✓		
Red clover	6	✓		✓		
White or yellow clover	2–3	✓		✓		
Grass-clover	3–4	✓		✓		
Cabbage spec.	3–4			✓	✓	
Celeriac	3			✓		
Leek	2–3			(✓)	✓	
Carrots	3–4			(✓)	✓	
Onions	4–5			✓	✓	

by spring crops. The time-span between pre-crop harvest and subsequent crop sowing allows sufficient time for accurate seedbed preparation, intensive mechanical weeding if necessary, and substantial root development and above-ground biomass for soil protection.

In response to the needs of different farm types, the proportion of the various crop groups used on the rotation will vary slightly (Table 3.3). Mixed farms with ruminants produce mainly rough fodder that can be part of the rotation of between 30 and 50% grass–clover or grass–alfalfa mixtures. Monogastric animals such as poultry and pigs are mainly fed by grains of legumes and cereals. Therefore, the proportions of legumes and cereals are shifting more to cereals and from forage to grain legumes. On arable farms the need for forage legumes is diminishing from the economical point of view. But from the perspective of sustainability, these farms should stay on at least a one-year set-aside system (Fragstein 1996). Cooperation between mixed farms (preferably organic) could expand the forage legume segment from one to two years, enable the import of animal manure as a substitute for the produced and exported forage fodder, and could keep the farm arable with great benefits for labour management (Nauta *et al.* 1999).

An alternative series of favourable rotational pairs are described by Baeumer (1992), although these need to be adjusted for specific site and crop conditions (Table 3.4). In more arid zones, spring cereals can be better suited than winter cereals. If harvest periods tend to be too late for the timely sowing of succeeding crops, early maturing cultivars have to be chosen for cultivation. Depending on soil moisture conditions, cover crops may be integrated into the rotational plan instead of partial fallows. Their value cannot be assessed only by narrow economic criteria. Indirect effects become more obvious over the longer term, including

Table 3.3 Examples for proportions (%) of typical crop groups (Freyer 2003)

Farm structure	Legumes	Cereals	Root crops	Cover crops
Mixed farm (milk cows)	30–50[A]	30–50	5–15	20–50
Mixed farm (various animals)	25–40[B]	40–60	10–20	20–50
Mixed farm (pigs)	20–35[C]	50–60	15–25	40–60
Arable farm	25–30[D]	40–60	20–30	40–60

[A] Mainly forage legumes; [B] forage legumes (>50%), grain legumes; [C] grain legumes, forage legumes, propagation of cover seeds, set-aside; [D] grain legumes, forage legumes, propagation of cover seeds, set-aside.

improvements in soil organisms, soil structure, soil management, trafficability, infiltration rate, and mineralisation rate.

In regions where rainfall is lower and/or less reliable, such as in Western Australia, simpler rotations with longer pasture or fallow phases are more likely. If the soil is heavier, with better nutrient and water retention, a suitable organic crop rotation would be pasture (vetch or medic *Medicago* spp. hay) > pasture > wheat > chickpeas > fallow > wheat. However, on lighter sandier soils, the rotation would consist of pasture > pasture (green manure) > wheat > oats or simply pasture > pasture > wheat (McCoy and Parlevliet 2001).

Additional benefits derived from cover cropping include weed and disease suppression. Approaches for managing weeds are discussed below; however, the main mechanism of weed suppression by cover crops appears to be resource competition, rather than factors such as allelopathy (Bond and Grundy 2001). The different occurrence of the fungal pathogen

Table 3.4 Favourable and unfavourable rotational pairs (Baeumer 1992)
1, very unfavourable; 2, unfavourable; 3, possible; 4, favourable; 5, very favourable.

	Succeeding crops												
Preceding crops	Grass-clover (perennial)	Winter rape	Sugar beet	Potatoes	Sunflower	Faba beans	Field peas	Maize (grain & silage)	Winter wheat	Winter barley	Winter rye	Spring barley	Oats
Grass–clover (perennial)	1	5	1	4	1	1	1	5	5	4	4	2	2
Winter rape	3	1	1	4	2	3	3	4	5	4	4	1	1
Sugar beet	3	1	1	4	2	2	2	5	5	1	1	4	3
Potatoes	3	5	5	2	2	2	2	5	5	5	5	4	3
Sunflower	3	1	4	4	1	4	4	4	5	5	5	4	4
Faba beans	2	1	2	5	1	1	1	5	5	4	4	3	3
Field peas	2	4	4	4	1	1	1	4	5	5	5	3	3
Maize (grain & silage)	3	1	5	5	5	5	5	3	4	2	2	4	4
Winter wheat	4	2	5	5	5	5	5	5	1	3	3	3	4
Winter barley	5	5	5	5	5	4	4	4	1	2	2	2	3
Winter rye	5	5	5	5	5	4	4	4	1	1	2	2	3
Spring barley	5	4	4	4	4	4	4	4	3	1	2	2	1
Oats	5	4	5	4	4	4	4	4	4	4	4	2	1

Table 3.5 Phytosanitary effect of grass–clover against the fungal pathogen Pseudocercosporella herpotrichoides (% infected plants) (Baeumer 1992)

Rotation A	%	Rotation B	%
Potatoes		Potatoes	
Oats		Oats	
Wheat	77.9	Wheat	44.7
Sugar beet		Grass–clover	
Oats		Grass–clover	
Vetch		Potatoes	
Wheat	78.9	Wheat	6.6

Pseudocercosperella herpotrichoides in a trial of two different seven year rotations (Table 3.5) was interpreted by Baeumer (1992) as a response to the replacement of sugar beet and oats by grass–clover, the interruption of the infection chain from wheat to wheat, and the decrease of the cereal proportion from 57% to 43%. Although these results were not obtained in organic farming systems, they are of direct relevance.

Cultural strategies used in organics

In addition to rotations, numerous other cultural practices are used in organic farming to achieve specific tasks or general whole-farm outcomes such as soil fertility, pest and disease management. These practices may range from the plethora of ongoing micromanagement decisions such as row widths and fertiliser timing, to the broader agroecological choices farmers make about farm layout and infrastructure.

Farm design

How can the development of rural landscape management be assessed? Stobbelaar and Mansvelt (2000) elaborated a detailed plan, according to which a series of European farm types and landscapes were evaluated. The quality of the (a)biotic environment was assessed by environmental and ecological criteria. The social environment was assessed by examining economic and sociological aspects, and the cultural environment was evaluated by psychological, physiognomic and cultural geography criteria. Whereas this approach needs several visits and working sessions at the site, another group of Dutch agronomists developed a methodology for the prototyping of farming systems in which the focus was distinctly more farm and production oriented, and in which the ecological infrastructure management was an essential component for the assessment of the environmental friendliness of each system. The parameters cover partly similar issues but are especially valid for agroecological assessment (Hopster and Visser 2001).

Farms are embedded in and are part of the landscape. Therefore, the management of farming systems intimately influences the quality of the environment at field, farm and regional levels. Detailed approaches to that topic were collected in a concerted action funded by EU grants (The Landscape and Nature Production Capacity of Organic/Sustainable Types of Agriculture, Mansvelt and Stobbelaar 1997, Stobbelaar and Mansvelt 2000). In line with broader concerns about the effect of agriculture on the environment, a question that has become steadily more relevant for organic practitioners is which farmland should be (re-)converted to or maintained as natural vegetation or habitat, and which should be kept for production? Various options exist to improve the landscape quality of a farm (Figure 3.3).

A

B

C

Figure 3.3 Options for improving the landscape quality of a farm (Mansvelt and Stobbelaar 1997). (A) Integrate individual trees or woodland into open pastures and fields. (B) Frame fields or field blocks by hedges built up with tree and bush vegetation. Follow natural landscape features (i.e. course of brocks or range of hills) for the implementation of further natural components. (C) Develop a web of different habitats for flora and fauna components, with improved connectivity between habitats. Limit the field widths so that they can be bridged by insects and other biotic elements to encourage the self-regulation mechanisms of agroecosystems. Increase the herbaceous species biodiversity with flowering corridors in big fields, less weeding passes and field margin management.

Table 3.6 Results of the survey among farmers – advantages and disadvantages of introducing natural elements (Hopster and Visser 2001)

Only farmers who thought it important arranged the advantages. All farmers who filled in the survey arranged the disadvantages. Rating scale used. 1 = most important, 5 = least important.

	Netherlands		Italy	Switzerland		Spain
	Int[A]	Org[B]		Int	Org	
Number of surveys	16	69	16	7	7	13
Is it important to introduce natural elements? (% Yes)	56	86	62	43	86	15
Advantages reported						
Subsidy	5	5	1	2	5	1
Natural predators	6	3	2	5	2	3
Biodiversity	3	2	3	2	1	6
Preventing erosion	4	6	5	1	2	4
Better image	2	4	4	2	4	5
Disadvantages reported						
Loss of income	2	3	4	__[C]	__[C]	3
Weeds	1	4	2	4	2	5
Loss of productive area	5	1	3	1	2	1
Possible hosts for diseases	4	5	5	7	5	4
Barriers for operation of machinery	3	2	1	__[C]	__[C]	2

[A] Int, integrated farming systems, [B] Org, organic farming systems; [C] Not asked in the Swiss survey.

On-farm biodiversity can be optimised over time and space by a range of strategies. Greater plant diversity can be produced by including a wider range of crops, using a mixture of cultivars, intercropping and polycultures, and planting companion species such as windbreaks and hedgerows (Bastiaans *et al.* 2000, Chikoye *et al.* 2001, MacLean *et al.* 2003, Nass *et al.* 2003, TangYa *et al.* 2003). Beyond the limits of the main production areas, landscape diversity also includes consideration of topography, watercourses, naturally vegetated areas and infrastructure related to the farm and the wider community (Kuiper 1997, Vereijken *et al.* 1997) (see Chapter 12 for a review of organic farming and the environment).

A survey among the vegetable farmers in four European countries, the Netherlands, Italy, Switzerland and Spain, resulted in very different perspectives and expectations of the farmers (Table 3.6). Additional subsidies were seen as the most important advantages by Italian and Spanish farmers. Biodiversity was scored highest by Swiss and Dutch organic farmers, whereas integrated farmers from Switzerland were most interested in erosion prevention, followed by better image, biodiversity and subsidy. Dutch integrated farmers only mentioned better image as an important criterion. As the most important disadvantages of introducing natural elements, the loss of productive area was most often mentioned (three times), problems with weed infestation mentioned only once, and barriers for operation of machinery indicated. Dependent on topography, farm size, experiences in and motivation for organic farming, the farmers' opinions reflected different personal backgrounds.

Planting densities

For several years, German organic cereal growers have been attracted by the wide-row concept developed by Stute (1996). To maximise the efficiency of limited N supply in an organic arable farm, cereals were sown in row distances between 40 and 50 cm. That system was primarily assessed for high quality wheat production (Germeyer 1999, Holle and Untiedt 1999, Becker and Leithold 2001, Richter and Debruck 2001) and for other crops drilled in line (Becker and Leithold 2003). Depending on the cultivars tested, grain yield losses can differ between negligible to substantial, particularly under the competition of living mulch systems (Germeyer 1999). Interestingly, increases in the protein content of grains were also observed, as in research in Northern Germany where a considerable increase in the glutene content that was higher than 2.0% of normally sown wheat (Holle and Untiedt 1999). Spring wheat was more responsive to that drilling design compared to winter wheat cultivars. The lower level of seeds used provided attractive economic figures, gain in lower seed costs combined with higher payments for better grain quality. Due to the wider spacing, undersowing should be integrated, at least at suitable sites. Reduced erodability was measured by Becker and Leithold (2003). The apparent increase of biodiversity in such an undersowing-oriented system (more space, more light, better growing factors for the undersown species) has to be paid for with higher labour input in terms of multiple mulching passes and costs for labour and the initial investment. However, very aggressive regulation of weeds is possible.

Weed management itself is important in determining crop densities and planting configurations. Wider rows are advantageous for weeding to allow access for tillage and hand-weeding implements, particularly under heavier weed loads (van Elzakker and Caldas 1999, Tillett and Home 2002, Rasmussen 2004). However, higher crop densities along the row achieved through closer transplant distances for seedling-grown crops or higher sowing rates for seed-grown crops are used to maximise resource capture and competition against weeds (Bulson *et al.* 1997, Grevsen 2000).

Timing of operations

The deliberate scheduling of farming activities is an important cultural strategy used by organic growers to manage resources efficiently and improve their effectiveness. The main factors for which timing can be manipulated include sowing, tillage, applying inputs and harvesting. Farmers' decisions about timing may be influenced by agronomic considerations such as crop phenology, the quantity and growth stage of weed seedlings, environmental factors such as climate and soil condition, and by marketing needs and opportunities.

Nitrate leaching can be an undesirable impact of organic crop production. Losses of mobile N of 100 kg ha^{-1} or more have been reported (Faßbender 1998), posing a serious economic and ecological problem, especially if continuous leakages within the rotation cannot be avoided. However, careful timing of farming operations such as fertiliser applications and green manure management to match availability with demand can be achieved. Conventional 'best practice' is designed to minimise nitrate leaching by improving the N use efficiency of crops, as well as protecting soil N from leaching during higher rainfall. Crop management factors affecting N dynamics include the selection of an appropriate crop variety, maintenance of a green cover for as much of the year as is practicable, and drilling crops early. Fertiliser management considerations include the calculation of fertiliser requirements using a recommendation system (and allowing for soil mineral N and any manures applied), spreading fertilisers evenly with a properly calibrated spreader (possibly with split applications) and using banding where appropriate. Irrigation water should also be applied carefully according to scheduling requirements.

Research is now focusing on the study of whole farm systems and the interactions between N losses and other pollutants to the environment, with the aim of minimising total environmental impact. In addition, increasingly sophisticated and reliable computer models are being developed to provide predictive capabilities for farm management tasks. Decision making about the timing of tasks within crop rotations is a process with many possible options and is, therefore, well suited to a modelling approach. Computer models have been developed and validated for the prediction of N fluxes in agroecosystems (Oomen and Habets 1998, Jensen *et al.* 2003), balancing tools were introduced for the estimation of nutrient and humus dynamics in agricultural systems and the validation of sustainability of farming systems (Hülsbergen 2003, van Delden *et al.* 2003, David *et al.* 2004), and spreadsheet calculations have been published by Stein-Bachinger *et al.* (2004) to support the estimation of N fluxes on the various levels of an organic farm (i.e. farm-gate, field, barn).

Weed management

According to an organic herb grower in Canada (Schimpf and Lundberg-Schimpf 2005):

> We're weeding 12 hours a day, 6 days a week. It would be 7 days but we need to irrigate every so often.

Are the weeds that bad in organic farming? In the seven years since the comment above was made, and after trying a range of methods, those herb growers have developed an integrated approach for managing the weeds so that they are not the major problem they were (Schimpf and Lundberg-Schimpf 2005). However, weed management is still one of the major issues in organic crop husbandry. Surveys of organic growers in many countries over several years have regularly indicated that weeds are a prime constraint, especially during conversion (Baker and Smith 1987, Peacock 1990, Beveridge and Naylor 1999, Walz 1999, Zinati 2002). Anecdotal reports among certifiers from organic farmers and the certification bodies confirm that weed control can be a key impediment in adopting, converting to and succeeding in organic production (Dumaresq *et al.* 1997). The conversion period can be particularly difficult because of lack of experience and significant changes in weed population dynamics (Ngouajio and McGiffen 2002).

As a result of the restrictions on synthetic herbicides, organic farming systems have to manage the various crops and weeds using a combination of indirect and direct methods of non-chemical weed regulation (Table 3.7). Indirect (cultural) methods consist of all techniques that are aimed at improving crop performance, to diminish the distribution of weed seeds and to suppress the development of weeds in the standing crop. Direct (physical) methods are designed to regulate weeds mechanically, manually, thermally or biologically. These techniques are used in conjunction with preventive and cultural methods for effective long-term weed management (Bàrberi 2002).

Weed reproduction and dispersal strategies are important factors in determining both their spread and their control. The problematic weeds in broadacre or intensive organic cropping systems tended to be either heavy seeding annuals or perennials with persistent underground parts such as stolons and rhizomes (Beveridge and Naylor 1999, Walz 1999). Heavy seeding annuals such as fat hen (*Chenopodium album*) and grasses (Poaceae) may be effectively controlled over time in organic cropping using a combination of seed bank depletion, avoiding conditions favourable for weed germination and growth, competitive crops and preventing further seed production (Bàrberi 2002). The common options available in organic agriculture such as tillage, mulching and rotations are usually effective. However, perennial weeds with persistent roots and shoots including couch (*Agropyron repens*), nutgrass (*Cyperus* spp.) and the docks (*Rumex* spp.) pose a far bigger problem as the usual options for organic farmers tend to be ineffective or they even encourage weed dispersion and growth (Lampkin 1990).

Canadian thistle (*Cirsium arvense*) is one of the most serious root weeds in organic crop husbandry (e.g. in cereals, potatoes and sugar beet), and is reported to be the fourth most problematic weed for United States organic growers (Walz 1999). The outcome of a farm survey of 140 farmers (Böhm and Verschwele 2004) clearly showed that thistles tended to become a serious problem on farms with a high proportion of cereals and summer-annual crops in the

Table 3.7 Methods of non-chemical weed management (after Köpke 2000)

Indirect methods	Direct methods
Crop rotation • competition • complementarity • allelopathy	**Mechanical** • hand weeding • various ploughs. chisel tines, discs, harrows, spring tines • rotary hoes • brush weeders • mulching
Farm hygiene • cleaning of seed supplies • cleaning machinery and tools	**Thermal** • flame weeders • steam weeders • infrared weeders
Soil cultivation • tillage (turning/non-turning) • photobiology	**Biological** • grazing with livestock • classical bio-control • 'bio-herbicides', microorganisms as weed pathogens
Improvement of competitiveness • seed quality • morphology and vigour of cultivars • drilling design. density, row distance, sowing direction • strategic fertilisation and irrigation	

rotation (>60%). On farms with a high percentage of clover, alfalfa and other mowable crops (~20%) thistles were not reported as critical. The effective suppression of thistles was as a result of:

(a) light competition through a fast-growing crop;
(b) root competition; and
(c) continuous destruction of shoots to exhaust the storage of assimilates in the roots (Radics *et al.* 2003, Pekrun and Claupein 2004, Lukashyk *et al.* 2005).

Therefore in crop rotations with a low level of forage legumes and a high level of cereals, farmers have to improve crop competition through adequate choice of cultivars (Köpke 2000), optimised growing conditions and fertiliser banding.

In perennial farming systems such as orchards and grazing enterprises, longer-lived weeds such as blackberry (*Rubus fruticosus*) and serrated tussock (*Nassella trichotoma*) may be favoured owing to the lack of ongoing disturbance (Sheppard 2000). Physical removal is suitable if the infestations are not too great. However, other options for managing perennial weeds include strategic grazing and biological control (Vere and Holst 1979, Evans and Bruzzese 2003).

Indirect methods

Some of the indirect methods used to manage weeds in organic cropping have been discussed above. In the sections on rotations and cultural strategies, a range of techniques for controlling weeds were mentioned including appropriate cropping sequences, growing two or more complementary crops in the same location, careful timing of input applications and strategic spatial arrangements of crop plants to optimise resource use efficiency and yield. Several other indirect methods are also used by organic growers to manage weeds in an integrated way. Many of these techniques may not individually contribute to large reductions in weed impacts, although they each have a role in an integrated weed management strategy, exemplified by the phrase 'many little hammers' (Liebman and Gallandt 1997).

Various techniques or approaches for improving the competitiveness of the main crop against weeds have been listed by Köpke (2000). Seed quality can strongly influence early crop growth and establishment, so selecting bigger seeds generally increases emergence rates and early vigour. Derrick and Ryan (1998) found that heavier wheat seeds had a higher P content and that germination, root biomass and shoot biomass were positively correlated with seed P levels. The morphological habit of cereal cultivars (e.g. erectophile v. planophile position of leaves) can be selected to improve weed suppression. The shadowing caused by the position of planophile leaves acts more against creeping dicotyledonous species, for example (Drews *et al.* 2002).

Germination in many weed seeds is phytochrome controlled. Seeds require light to stimulate germination and this is usually provided when soil is tilled (Scopel *et al.* 1994, Milberg 1997). Several researchers have investigated the impact of preventing light exposure during tillage by cultivating at night or with covered implements, and have found that reductions in density and biomass for a range of weeds are often obtained, although the results vary considerably and are difficult to predict (Melander 1998a, Fogelberg 1999). Several factors have been reported to influence variability in weed seed behaviour, including non-responsiveness to light in certain species, interactions with chemical and physical conditions, intra-population dormancy differences, land use history and current tillage practices (Milberg *et al.* 1996, Milberg 1997, Botto *et al.* 1998, Gallagher and Cardina 1998).

When sowing crops, drilling in an east–west direction can provide better shadowing of interrow space and light interception by the crop. The occurrence of *Apera spica-venti* could be reduced more under erectophile cultivars drilled from east–west compared to north–south. The effect of planophile cultivars was similar in both drilling directions tested (Köpke 2000).

Direct methods

Mechanical weed control

Whereas chemical weed control often achieves 100% efficacy against various monocotyledonous or dicotyledonous plants, tools for mechanical weeding are much less effective and reliable. Their effectiveness depends upon various factors such as soil type and status, type of target plant and growth stage, and the technical design aspects of the implement. In addition to limitations of poor accuracy, soil damage and promoting further weed flushes, tillage implements cannot be used on time if climatic conditions are unfavourable (Fogelberg and Dock Gustavsson 1999, Hatcher and Melander 2003). Nevertheless, mechanical cultivation remains a prominent element of most organic weed management programs and Ehlers (1997) points out that improved soil structure and accelerated seedling growth can occur after ploughing, increasing the competitiveness of crops against weeds. See Special Topic 2 for the impact of tillage on soils in organic farming.

According to Dierauer and Stöppler-Zimmer (1994) the chain harrow and the harrow comb are very suitable for cereals and suitable for all other crops and crop groups (Table 3.8). Selectivity of harrows can be influenced by the day of treatment, composition of weed flora, site characteristics and the degree of weed control (Rasmussen 1992). The use of cultivators promises the best results in nearly all cultivated crops, although different harrow types fit better for weed regulation in cereal crops. Finger weeders are best suited for potatoes, maize and beet. High investment costs (brush hoes) and high energy costs (flame weeder) are only justifiable in crops with high gross margins, such as market gardens or other high-value crops

Table 3.8 Suitability of various tillage implements for non-chemical weed regulation (Dierauer and Stöppler-Zimmer 1994)
0, not suitable; 1, possible; 2, suitable; 3, very suitable.

Crop	Chain harrow	Harrow comb	Culti-vator	Finger weeder	Brush hoe	Rotary hoe	Flame weeder
Cereals	3	3	2	0	1	0	0
Potatoes	2	2	3	3	0	2	0
Maize	2	2	3	3	2	2	2
Rape	2	2	3	1	1	1	0
Beet	2	2	3	3	2	2	2
Beans	2	2	3	1	1	1	0
Field vegetables	2	2	3	1	3	2	3
Pasture	2	2	0	0	0	0	0

like medicinal herbs (Melander 1998a). Using empirical data and modelling, Nemming (1994) indicated that farm size also had an impact on the cost effectiveness of flame weeding.

Night-time cultivation, or sowing under dark conditions, was an effective method for reducing weed levels (Hartmann and Nezadal 1990, Gerhards *et al.* 1998, Juroszek 1999), although other authors (Jensen 1992, Niemann 1996) could not confirm these findings. Nonetheless, the photobiological control of light germinating weeds should be the subject of further research and later, implementation in practice.

A range of less commonly used methods that rely on some form of heat to control weeds and their seeds have been tested and implemented. These methods have the advantage of achieving thorough control of at least one cohort of weeds without reliance on mechanical cultivation, and the techniques are commonly used in the preparatory phase, prior to sowing or planting. Soil solarisation is a viable alternative in higher-value intensive horticulture (Stapleton *et al.* 2005), although this method is selective in the weeds controlled, requires extended periods of warm weather and usually requires single-use, non-recyclable plastic sheeting (Henderson and Bishop 2000).

Hand weeding

Hand weeding is commonly used by organic growers (Beveridge and Naylor 1999, Walz 1999, Kristiansen *et al.* 2001), particularly in developing countries where labour may be cheaper and more readily available and where access to machinery less common (Johnson 1995, Chatizwa 1997). This weeding method is carried out as either a central method of weed management or as a supplement to other methods, and has the advantage of providing good selective control unavailable with other methods such as tillage (Pratley 2000). The key limitation for hand weeding in many situations is that the time and labour requirements are too large or too costly (Johnson 1995, Anuebunwa 2000, Melander and Rasmussen 2001). However, where the cost of inputs and the value of outputs are suitably matched, for example a high value vegetable crop, hand weeding can be cost effective. Alemán (2001) found that hand weeding of beans (*Phaseolus vulgaris*) in Nicaragua was more profitable compared to herbicides.

Although hand weeding is very common, research aimed at improving its efficiency is considerably less common. Development agencies have stressed the need to improve the efficacy of tools used by women, who are ‘often responsible for a large portion of food production’, in farm work in developing countries (Women in Development Service, FAO, 2001). Wheel-mounted hoes have been designed that enable larger areas to be weeded with less physical strain, and greater selectivity between crop and weed than a conventional hand hoe (Wilkie and Plane 2000). Other recent developments in hand weeding technology include self-propelled and tractor-drawn platforms on which people lie while moving along crop rows and weed by hand (Leinonen and Närkki 2000, Bishop *et al.* 2002).

Mulches

Mulches can be used economically in many organic horticultural crops including annual herbs and vegetables as well as perennial vine and tree crops. In addition to suppressing weeds, organic mulches have other benefits such as conserving soil and moisture, reducing soil temperature fluctuations, adding organic matter and nutrients to the soil and preventing soil from splashing onto crop leaves (Patriquin 1988, Teasdale and Mohler 1993, Whitten 1999). Materials used as organic mulches include compost and manures, crop residues (ash, grass, hay, *in situ* residues, starch, straw), tree products (bark, sawdust and woodchips), fibre products (fabric, jute, coconut fibre, wool), and paper products (pellets, sheets, rolls, chopped, shredded).

Synthetic mulches are allowed for limited use in organic production (IFOAM 2002) and offer many of the benefits of organic mulches but are considered less sustainable owing to the non-renewable source materials, energy required in manufacture, single usage limitation and long-term disposal requirements (Olsen and Grounder 2001). Woven plastic material, such as weed matting, is permitted for restricted, short-term use only. Shade cloth (Sutton 1998) and weed matting (Monks *et al.* 1997) have been used in conventional vegetable production, and weed matting has been tested in organic peach (*Prunus persica*) orchards (Zimmerman 2002), but few examples were identified in the literature about the use of these synthetic mulches for organic herb and vegetable growing (Birkeland and Døving 2000, Radics and Székelyné Bognár 2002).

Several problems have been reported with the use of mulches for weed control including acquiring enough material, transporting and handling and laying large amounts of often bulky material, cost of materials, introducing weed seeds, applying an inadequate depth and interfering with crop growth harvesting (Henderson and Bishop 2000). The negative effects of mulches on crop yield are related to several mechanisms including nutrient immobilisation (especially N), phytotoxin release, poor weed control, increased pests levels and modified soil aeration, moisture and temperature (Teasdale 1998, Leary and Defrank 2000).

With regard to mulch handling and application, the lack of efficient equipment for laying organic mulches is a serious constraint to wider usage (Olsen and Gounder 2001, Schäfer *et al.* 2001). Strategies for reducing the costs of laying mulch include the use of novel materials such as flowable, pelletised mulches (Smith *et al.* 1997), spray-on mulch (Russo 1992) or paper rolls that could be applied in a similar way to polythene mulch (Runham *et al.* 2000). *In situ* mulches such as cover crops grown on site and terminated (mechanically or through senescence) prior to planting a vegetable crop, offer the benefit of reducing mulch handling costs, although skilled management is required to grow effective weed-suppressing mulches while optimising growth of the subsequent cash crop (Abdul-Baki and Teasdale 1997, Creamer and Dabney 2002, Ngouajio *et al.* 2003). Ngouajio and Mennan (2005) report that fresh rye (*Secale cereale*) residue can interfere with planting seedlings and that, despite good weed suppression by hairy vetch (*Vicia villosa*), subsequent cucumber yields were unacceptably low.

Grazing

Organic agriculture has traditionally relied on the integration of livestock and cropping phases for various functions including weed control, crop protection and fertility management (Köpke and Geier 1999). More recently, the international organic movement is now heavily dominated, in terms of the land area certified, by extensive grazing systems, principally in Australia and Argentina (Willer and Yussefi 2005). Globally, a diverse range of animals are used to control weeds on organic farms including poultry, goats, cattle and pigs. The animals may be used for different tasks such as ground preparation and removing rhizomatous weeds by pigs or post-harvest weed seed removal by sheep (Clark *et al.* 1995, Andresen 1998). However, the use of grazing and livestock phases has not always been adopted by farmers converting to organic production methods and, in many cases, farmers opt for stockless systems to reduce the complexity of farm management and to focus on other plant-based commodities (Huxham *et al.* 2001).

Thermal weed control

Flame and steam weeders are implements suited to annual and perennial horticultural systems (Melander and Rasmussen 2001, Penfold 2001) as well as arable cropping systems (Rasmussen 2003). These tools have been gaining in popularity among organic growers and gas supply companies as new designs are being built and tested (Daar 2002), and as basic knowledge about dose-response patterns (Storeheier 1994, Ascard 1995, Bàrberi *et al.* 2002) and the wider ecological impacts is acquired (Rahkonen *et al.* 1999).

Flame and steam weeders are often used with good success in the pre-emergence and early postemergence stages of a crop. However, the technique is limited by short suitable application time periods and poor control in certain weed species, especially monocotyledonous plants with shielded meristems (Ascard 1995). Steam weeders usually provide better heat transfer efficiency than flame weeders, although further research is needed to improve the fuel use and heat transfer of thermal weeding units generally (Merfield 2002).

Biological methods

The use of weed-specific biological agents is a valid technique for managing weeds in organic and other farming systems. However, despite the compatibility of biological control and organic agriculture, these methods are not common practice within the organic farming movement (Köpke 2000, Kristiansen 2003). Classical biocontrol may be less suited to annual cropping systems in which the control agent's habitat may be disturbed or completely removed from time to time, or if farming operations (e.g. tillage) interfere with the lifecycle of the control agent (Hartley and Forno 1992). For weeds in organic cropping that commonly have perennial rhizomatous organs with a strong regeneration capacity, biocontrol programs have been persistent failures (Hartley and Forno 1992). In a review of the current development of biological weed control methods in association with physical and cultural methods, Hatcher and Melander (2003) recommend using combined control methods and stress the importance of strategic timing to maximise damage to the weed and minimise damage to the biocontrol agent.

More research is needed to ensure the use of pathogen, dosage, environmental conditions and potential success of applications. However, these new organisms have to be registered and permitted as microbial products for certified organic weed management. Another group of products are the mycoherbicides or bioherbicides requested by some organic farmers, but criticised and disputed by organic organisations and some 'organic purists' (Verschwele 2005). If these new products become listed as crop husbandry inputs in the organic standards, precise restrictions will need to be included with allowance for their optional application (e.g. before use, all indirect and partially direct weeding methods must have been tested).

Weeds as indicators

There are publications within the organic movement that relate the occurrence of specific weeds to specific soil conditions and that refer to the possibility of weeds being 'indicators' of soil status (e.g. Pfeiffer 1970, Walters 1996). The presence of a given weed therefore suggests that the land has too much or too little of a certain soil feature (e.g. drainage, pH, copper levels) that may be modified by the farm manager. Although many of the recommendations are based on careful observation and commonsense, some of the relationships have not been conclusively established.

Tilman *et al.* (1999) investigated the relationship between dandelion (*Taraxacum officinale*) abundance and soil K. Three key pieces of evidence exist:

(a) clear correlation of K and dandelion abundance in the 140-year-old Park Grass Experiment at Rothamsted, UK;
(b) greenhouse trials showing that dandelion had higher K requirements than several common grasses; and
(c) dandelion abundance was positively correlated with tissue K concentrations.

This research suggests that adjustments in resource supply rates influence interspecific competition where plant species differ in their resource requirements. Such knowledge provides potential for encouraging beneficial species to competitively control weedy species (Tilman *et al.* 1999).

More generally, Walter *et al.* (2002) tested the spatial cross-correlation between weed species and several soil properties. Certain weeds were correlated with specific soil chemical properties (e.g. P, pH); however, other species did not show consistent correlation with soil types between fields and sampling times, and some were correlated with more than one soil property. The most consistent relationship was between weed density and clay content. This result suggests that weeds have different resource requirements and that modifying soil conditions to manage certain weeds may promote others.

Conclusions

Organic crop husbandry relies principally on rotational management, and increasing the diversity of species in space and time to maximise biological and ecological services. There is a need for sufficient soil fertility building components in the rotation, such as grass–clover–lays, for sufficient N accumulation by legumes and for adequate nutrient transfer from preceding to succeeding crop. In addition to soil fertility maintenance and nutrient management improvement, well-designed crop rotations contribute to the prevention of disease, pest and weed problems. These aims must be fulfilled under many varying site conditions, requiring awareness of the particular agroecosystem, as well as skilled management. Increasingly, the organic standards require that farming practices allow for a greater proportion of natural components to be maintained in the farm design. This diversity can be highly effective in creating a self-regulatory system, with less reliance on external inputs.

Although organic farming commonly exhibits higher tolerance towards the occurrence of wild flora in growing crops, weed regulation is one of the key constraints in organic crop production. Depending on farm size and the level of mechanisation, the tools can vary from hand labour, hand-hoeing tools to a group of mechanical and thermal machines. Intrarow weeding has traditionally required high labour input due to a lack of adequate implements, although developments in engineering have improved the suite of tools available to the organic grower.

Several areas requiring further research in organic crop production include improving nutrient supply–demand matching, overcoming specific nutrient limitations (e.g. P), investigating the role of landscape elements such as hedges and windbreaks, and developing new tools and identifying successful strategies for weed management.

References

Abawi, G.S. and Vogel, C. 2000. Evaluation of green manures of marigold against root-knot nematode on lettuce, 1998–1999. In *Biological and Cultural Tests for Control of Plant Diseases*. American Phytopathological Society Press, St. Paul.

Abdul-Baki, A.A. and Teasdale, J.R. 1993. A no-tillage tomato production system using hairy vetch and subterranean clover mulches. *HortScience* 28(2): 106–108.

Abdul-Baki, A.A. and Teasdale, J.R. 1997. Snapbean production in conventional tillage and in no-tillage hairy vetch mulch. *HortScience* 32(7): 1191–1193.

Advisory Committee on Organic Standards 2004. *Compendium of UK Organic Standards*. Department for Environment, Food and Rural Affairs, London.

Albrecht, H. 2003. Suitability of arable weeds as indicator organisms to evaluate species conservation effects of management in agricultural ecosystems. *Agriculture, Ecosystems and Environment* 98(1–3): 201–211.

Alemán, F. 2001. Common bean response to tillage intensity and weed control strategies. *Agronomy Journal* 93(3): 556–563.

Altieri, M.A. 1999. The ecological role of biodiversity in agroecosystems. *Agriculture, Ecosystems and Environment* 74(1–3): 19–31.

Altieri, M.A. and Letourneau, D.K. 1982. Vegetation management and biological control in agroecosystems. *Crop Protection* 1(4): 405–430.

Andresen, N.K. 1998. Soil tillage of pigs on grassland. Consequences for the following winter wheat crop. In. Foguelman, D. and Lockeretz, W. (eds) *Organic Agriculture – the Credible Solution for the XXIst Century. Proceedings of the 12th International IFOAM Scientific Conference*. International Federation of Organic Agriculture Movements, Mar del Plata. pp. 250–253.

Anuebunwa, F.O. 2000. A bio-economic on-farm evaluation of the use of sweet potato for complementary weed control in a yam/maize/egusi/cassava intercrop in pigeon pea hedgerows in the rain forest belt of Nigeria. *Biological Agriculture and Horticulture* 18(2): 95–102.

Ascard, J. 1995. Effects of flame weeding on weed species at different developmental stages. *Weed Research* 35(5): 397–411.

Ascard, J. 1998. Comparison of flaming and infrared radiation techniques for thermal weed control. *Weed Research* 38: 69–76.

Augstburger, F., Milz, J., Rivera, A., Rivera, E. and Schnepel, G. 2002. Bolivian and Nicaraguan experience with ecological agroforestry: a 'natural succession system' as proposed by Ernst Götsch. In: Thompson, R. (ed.) *Cultivating Communities. Proceedings of the 14th IFOAM Organic World Congress*. Victoria, Canada, 21–28 August 2002. Canadian Organic Growers, Ottawa. p. 135.

Baker, J.P. and Smith, D.B. 1987. Self identified research needs of New York organic farmers. *American Journal of Alternative Agriculture* 2(3): 107–113.

Baeumer, K. 1992. *Allgemeiner Pflanzenbau*. Eugen Ulmer Verlag, Stuttgart.

Bàrberi, P. 2002. Weed management in organic agriculture: are we addressing the right issues? *Weed Research* 42(3): 177–193.

Bàrberi, P., Moonen, A.-C., Peruzzi, A., Rafaellli, M. and Mazzoncini, M. 2002. Reducing weed seedling recruitment by soil steaming. In: Thompson, R. (ed.) *Cultivating Communities. Proceedings of the 14th IFOAM Organic World Congress*. Victoria, Canada, 21–28 August 2002. Canadian Organic Growers, Ottawa. p. 48.

Bastiaans, L., Kropff, M.J., Gourdriaan, J. and van Laar, H.H. 2000. Design of weed management systems with a reduced reliance on herbicides poses new challenges and prerequisites for modelling crop-weed interactions. *Field Crops Research* 67(2): 161–179.

Baumann, D.T., Bastiaans, L and Kropff, M.J. 2001. Competition and crop performance in a leek–celery intercropping system. *Crop Science* 41(3): 764–774.

Becker, K. and Leithold, G. 2001. Praxiseinführung des Anbaukonzeptes Weite Reihe unter besonderer Berücksichtigung des Qualitätsaspektes bei Backweizen. In: Reents, H.J. (ed.) *Beiträge zur 6. Wissenschaftstagung zum Ökologischen Landbau – von Leit–Bildern zu Leit–Linien*. Verlag Dr Köster, Berlin, pp. 429–432.

Becker, K. and Leithold, G. 2005. Ausweitung des Anbaukonzeptes Weite Reihe bei Winterweizen auf Roggen Hafer, Raps und Körnerleguminosen. Eine pflanzenbauliche und betriebswirtschaftliche Untersuchung unter Berücksichtigung der Vorfruchtwirkungen. In: Heß, J. and Rahmann, G. (eds) Ende der Nische – Beiträge zur 8. Wissenschaftstagung Ökologischer Landbau, Kassel University Press, Kassel. pp. 233–234.

Beveridge, L.E. and Naylor, R.E.L. 1999. Options for organic weed control – what farmers do. In: Marshal, G. (ed.) *Weeds. Proceedings of the 1999 Brighton Conference.* –15–18 November 1999. British Crop Protection Council, Surrey. pp. 939–944.

Birkeland, L. and Døving, A. 2000. Development of organic strawberry production in Norway: cultivars and mulching materials. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *IFOAM 2000 – The World Grows Organic. Proceedings of the 13th International IFOAM Scientific Conference.* Convention Centre Basel, Switzerland 28–31 August 2000. vdf Hochschulverlag AG an der ETH Zurich, Basel. p. 207.

Bishop, A., Dennis, J., French, J. and Gardam, P. 2002. Going organic. A study of weed management in an intensive organic vegetable production system. In. Spafford Jacob, H., Dodd, J. and Moore, J.H. (eds) *13th Australian Weeds Conference. Proceedings and Papers.* 8–13 September 2002. Plant Protection Society of WA, Perth. pp. 218–221.

Böhm, H. and Verschwele, A. 2004. *Ampfer- und Distelbekämpfung im Ökologischen Landbau. Statusseminar Ressortforschung für den Ökologischen Landbau 2003.* pp. 39–48. Biologischen Bundesanstalt (Hrsg), Kleinmachnow.

Bond, W. and Grundy, A.C. 2001. Non-chemical weed management in organic farming systems. *Weed Research* 41(5): 383–405.

Botto, J.F., Scopel, A.L., Ballare, C.L. and Sánchez, R.A. 1998. The effect of light during and after soil cultivation with different tillage implements on weed seedling emergence. *Weed Science* 46(3): 351–357.

Brandsæter, L.O. and Riley, H. 2002. Cover crops and mulches for weed control in organically grown vegetables. In: Cloutier, D.C. (ed.) *Proceedings of the 5th EWRS Workshop on Physical and Cultural Weed Control.* European Weed Research Society, Pisa. p. 174.

Bugg, R.L., McGourty, G., Sarrantonio, M., Lanini, W.T. and Bartolucci, R. 1996. Comparison of 32 cover crops in an organic vineyard on the north coast of California. *Biological Agriculture and Horticulture* 13(1): 63–81.

Bulson, H.A., Welsh, J.P., Stopes, C.E., Woodward, L., 1996. Agronomic viability and potential economic performance of three organic four year rotations without livestock 1988–1995. *Aspects of Applied Biology* 47: 277–286.

Bulson, H.A.J., Snaydon, R.W. and Stopes, C.E. 1997. Effects of plant density on intercropped wheat and field beans in an organic system. *Journal of Agricultural Science* 128(1): 59–71.

Chatizwa, I. 1997. Mechanical weed control. The case of hand weeders. Brighton Crop Protection Conference – *Weeds* 1: 203–208.

Chikoye, D., Ekeleme, F. and Udensi, U.E. 2001. Cogongrass suppression by intercropping cover crops in corn/cassava systems. *Weed Science* 49: 658–667.

Clark, M.S., Gage, S.H., DeLind, L.B. and Lennington, M. 1995. The compatibility of domestic birds with a nonchemical agroecosystem. *American Journal of Alternative Agriculture* 10(3): 114–121.

Creamer, N.G. and Dabney, S.M. 2002. Killing cover crops mechanically: review of recent literature and assessment of new research results. *American Journal of Alternative Agriculture* 17(1): 32–40.

Creamer, N.G., Bennett, M.A., Stinner, B.R. and Cardina, J. 1996. A comparison of four processing tomato production systems differing in cover crop and chemical inputs. *Journal of the American Society for Horticultural Science* 121(3): 559–568.

Daar, S. 2002. *Flame Weeding in the Garden*. Gameco, Milton. <http://www.gameco.com.au/Flame%20Weeding.htm>. Accessed 7/5/05.

David, C., Jeuffroy, M.H., Recous, S. and Dorsainvil, F. 2004. Adaptation and assessment of the Azodyn model for managing the nitrogen fertilization of organic winter wheat. *European Journal of Agronomy* 21(2): 249–266.

Derrick, J.W. and Ryan, M.H. 1998. Influence of seed phosphorus content on seedling growth in wheat. implications for organic and conventional farm management in south east Australia. *Biological Agriculture and Horticulture* 16(3): 223–237.

Dierauer, H.U. and Stöppler-Zimmer, H. 1994. *Unkrautregulierung ohne Chemie*. Eugen Ulmer Verlag, Stuttgart.

Drews, S., Juroszek, P., Neuhoff, D. and Köpke, U. 2002. Competitiveness of winter wheat stands against weeds: effects of cultivar choice, row width and drilling direction. In: Thompson, R. (ed.) *Cultivating Communities. Proceedings of the 14th IFOAM Organic World Congress*. Victoria, Canada, 21–28 August 2002. Canadian Organic Growers, Ottawa. p. 17.

Dumaresq, D., Greene, R. and van Kerkhoff, L., eds 1997. *Organic Agriculture in Australia. Proceedings of the National Symposium on Organic Agriculture*. Research and Development 30 June–3 July, 1996. Rural Industries Research and Development Corporation, Barton.

Edmeades, D.C. 2003. The long-term effects of manures and fertilisers on soil productivity and quality. a review. *Nutrient Cycling in Agroecosystems* 66(2): 165–180.

Ehlers, W. 1997. Influence of cultural intensity on water use and water use efficiency – basic considerations and deductions for organic farming. In: Isart, J. and Llerena, J.J. (eds) *Resource Use in Organic Farming. Proceedings of the 3rd ENOF Workshop*. The European Network for Scientific Research and Coordination in Organic Farming, Ancona. pp. 7–22.

Evans, K.J. and Bruzzese, E. 2003. Life history of *Phragmidium violaceum* in relation to its effectiveness as a biological control agent of European blackberry. *Australasian Plant Pathology* 32(2): 231–239.

Evans, J., Scott, G. Lemerle, D. Kaiser A., Orchard, B., Murray, G.M. and Armstrong, E.L. 2003. The impact of legume 'break' crops on the yield and grain quality of wheat and relationship with soil mineral N and crop N content. *Australian Journal of Agricultural Research* 54: 777–788.

Faßbender, K. 1998. Strategien zur Reduzierung von Nitratverlagerungen auf ökologisch wirtschaftenden Betrieben im ersten und zweiten Jahr nach Kleegrasumbruch. Verlag M. Wehle, Witterschlick/Bonn, Beiträge zu Agrarwissenschaften Bd 16.

Finckh, M.R. and Wolfe, M.S. 1998. Diversification strategies. In: Jones, D.G. (ed.) *The Epidemiology of Plant Diseases*. Chapman and Hall, London. pp. 231–259.

Fogelberg, F. 1999. Night-time soil cultivation and intra-row brush weeding for weed control in carrots (*Daucus carota* L.). *Biological Agriculture and Horticulture* 17(1): 31–45.

Fogelberg, F. and Dock Gustavsson, A.M. 1999. Mechanical damage to annual weeds and carrots by in–row brush weeding. Weed Research 39, 469–479.

Fowler, C.J.E., Condron, L.M. and McLenaghen, R.D. 2004. Effects of green manures on nitrogen loss and availability in an organic cropping system. *New Zealand Journal of Agricultural Research* 47(1): 95–100.

Fragstein und Niemsdorff, P. von, Geyer, B. and Reents, H.J. 2004. BLE-Projekt 02OE222 – Status quo. *Ökologischer Gemüsebau – Betriebsbefragungen*. Abschlussbericht.

Fragstein, P. von 1996. Organic arable farming – a contradiction? In: van Ittersum, M.K. Venner, G.E.G.T. van de Gijn, S.C. and Jetten. T.H. (eds) *Book of Abstracts*. European Society for Agronomy. Veldhoven-Wageningen. pp. 438–439.

Francis, CA. 1986. *Multiple Cropping Systems*. Macmillan Publishing Company, New York.
Freyer, B. 2003. *Fruchtfolgen*. Eugen Ulmer Verlag, Stuttgart.
Gallagher, R.S. and Cardina, J. 1998. The effect of light environment during tillage on the recruitment of various summer annuals. *Weed Science* 46(2): 214–216.
Gerhards, R., Juroszek, P., Klümper, H. and Kühbauch, W. 1998. Möglichkeiten zur photobiologischen Unkrautregulierung auf Ackerschlägen. *Pflanzenbauwissenschaften* 2: 91–96.
Germeyer, C.U. 1999. Weitreihenverfahren und Lebendmulch – neue Anbaukonzepte für den Ökologischen Landbau? In: Hoffmann, H. and Müller, S. (eds) Beiträge zur 5. Wissenschaftstagung zum Ökologischen Landbau – Vom Rand zur Mitte. Verlag Dr Köster, Berlin. pp. 82–85.
Gosling, P. and Shepherd, M. 2005. Long-term changes in soil fertility in organic arable farming systems in England, with particular reference to phosphorus and potassium. *Agriculture, Ecosystems and Environment* 105: 425–432.
Grevsen, K. 2000. Competitive ability of pea (*Pisum sativum* L.) cultivars against weeds. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *IFOAM 2000 – The World Grows Organic. Proceedings of the 13th International IFOAM Scientific Conference*. vdf Hochschulverlag AG an der ETH Zurich, Basel. pp. 179.
Haas, G. 2004. *Stickstoffversorgung von Weisskohl, Silo- und Körnermais durch Winterzwischenfrucht–Leguminosen*. Schriftenreihe Institut für Organischen Landbau. Verlag Dr Köster, Berlin.
Hartley, K.L.S. and Forno, I.W. 1992. *Biological Control of Weeds: A Handbook for Practitioners and Students*. Inkata Press, Melbourne.
Hartley, M.J., Rahman, A, Harrington, K.C. and James, T.K. 2000. Assessing ground covers in a newly planted apple orchard. *New Zealand Plant Protection* 53: 22–27.
Hartmann, K.M. and Nezadal, W. 1990. Photocontrol of weeds without herbicides. *Naturwissenschaften* 77: 158–163.
Hatcher, P.E. and Melander, B. 2003. Combining physical, cultural and biological methods. prospects for integrated non-chemical weed management strategies. *Weed Research* 43(5): 303–322.
Henderson, C.W.L. and Bishop, A.C. 2000. Vegetable weed management systems. In: Sindel, B.M. (ed.) *Australian Weed Management Systems*. R.G. and F.J. Richardson, Melbourne. pp. 355–372.
Herrmann, G. and Plakolm, G. 1991. *Ökologischer Landbau – Grundwissen für die Praxis*. Österreichischer Agrarverlag, Wien.
Heß, J. 1993. *Residualer Stickstoff aus mehrjährigem Feldfutterbau: Optimierung seiner Nutzung durch Fruchtfolge und Anbauverfahren unter den Bedingungen des Ökologischen Landbaus*. Habilitationsschrift, Landwirtschaftliche Fakultät, Universität Bonn.
Holle, R. and Untiedt, H. 1999. Crop rotations on organic farms in Northern Germany and development of wide row system. In: Olesen, J.E., Eltun, R., Gooding, M.J., Jensen, E.S. and Köpke, U. (eds) *Designing and Testing Crop Rotations for Organic Farming – Proceedings from an International Workshop*. Danish Research Centre for Organic Farming, Tjele, pp. 159–162.
Hooks, C.R.R., Valenzuela, H.R. and Defrank, J. 1998. Incidence of pests and arthropod natural enemies in zucchini grown with living mulches. *Agriculture, Ecosystems and Environment* 69: 217–231.
Hopster, G.K. and Visser, A.J. (eds) 2001. Ecological infrastructure management. Proceedings of VEGINECO, FAIR 3–CT96–2056, *Integrated and Ecological Vegetable Production, Development of Sustainable Farming Systems Focusing on High Quality Production and Minimum Environmental Impact*. Applied Plant Research BV, Wageningen.

Hülsbergen, K.J. 2003. *Entwicklung und Anwendung eines Bilanzierungsmodells zur Bewertung der Nachhaltigkeit landwirtschaftlicher Systeme. Berichte aus der Agrarwirtschaft*. Shaker Verlag, Aachen.

Hutchinson, C.M. and McGiffen, M.E. 2000. Cowpea cover crop mulch for weed control in desert pepper production. *HortScience* 35(2): 196–198.

Huxham, S., Sparkes, D. and Wilson, P. 2001. *Organic Conversion Strategies for Stockless Farming Systems*. University of Nottingham. Nottingham

IFOAM 2002. *Final Draft 2002. Basic Standards for Organic Production and Processing.* International Federation of Organic Agriculture Movements, Tholey-Theley, Germany.

Iqbal, Z., Hiradate, S., Noda, A. Isojima, S. and Fuji, Y. 2003. Allelopathic activity of buckwheat: isolation and characterization of phenolics. *Weed Science* 51(5): 657–662.

Jambhekar, H. 2003. *Managing the Vital Energy in Agriculture – A New Indian Concept Adopted From Ancient Indian Text*. Food and Agriculture Organization of the United Nations. Rome. <http://www.fao.org/DOCREP/ARTICLE/AGRIPPA/656_en00.htm>. Accessed 19/12/05.

Jensen, L.S., Müller, T., Eriksen, J., Thorup-Kristensen, K. and Magid, J. 1999. Simulation of plant production and N fluxes in organic farming systems with the soil–plant atmosphere model DAISY. In: Olesen, J.E., Eltun, R., Gooding, M.J., Jensen, E.S. and Köpke, U. (eds) *Designing and Testing Crop Rotations for Organic Farming – Proceedings from an International Workshop*. Danish Research Centre for Organic Farming, Tjele, pp. 235–248.

Jensen, P.K. 1992. First Danish experiences with photocontrol of weeds. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz* 8: 631–636.

Johnson, D.E. 1995. Weed management strategies for smallholder rice production. Brighton Crop Protection Conference. *Weeds* 3: 1171–1180.

Juroszek, P. 1999. Photobiologische Unkrautkontrolle. Diss. Agr. Universität Bonn.

Kahnt, G. 1986. *Biologischer Pflanzenbau – Möglichkeiten und Grenzen biologischer Anbausysteme*. Eugen Ulmer Verlag, Stuttgart.

Kahnt, G., Keller, E.R. and Köpke, U. 1997. Ökologischer Landbau. In: Hanius, H. Heyland, K.U. and Keller, E.R. (eds) *Handbuch des Pflanzenbaus, Eugen Ulmer Verlag.* 1: 625–702.

Kluth, S., Kruess, A. and Tscharntke, T. 2003. Influence of the mechanical cutting and pathogen application on the performance and nutrient storage of *Cirsium arvense*. *Journal of Applied Ecology* 40: 334–343.

Köpke, U. and Geier, U. 1999. Mixed farming on bio-regional level. current issues and new perspectives. In: Zanoli, R. and Krell, R. (eds) *First SREN Workshop on Research Methodologies in Organic Farming. Proceedings*. Frick, Switzerland. 30 September–3 October 1998. Food and Agriculture Organization of the United Nations, Rome. pp. 95–99.

Köpke, U. 2000. Konzept der Unkrautregulierung im Ökologischen Landbau. In: Pallut, B (ed.) *Pflanzenschutz im Ökologischen Landbau – Probleme und Lösungsansätze – Drittes Fachgespräch am 2. Nov. 1999 in Kleinmachnow Unkrautregulierung im Ökologischen Landbau. Berichte aus der Biologischen Bundesanstalt für Land- und Forstwirtschaft* 72: 57–70.

Kristiansen, P. 2003. *Sustainable Weed Management in Organic Herb and Vegetable Production*. University of New England, Armidale. Doctor of Philosophy thesis.

Kristiansen, P.E., Jessop, R.S. and Sindel, B.M. 2001. Organic weed management survey: methods used by Australian herb and vegetable growers. In: Rowe, B., Mendham, N. and Donaghy, D. (eds) *Science and Technology: Delivering Results for Agriculture*. 10th Australian Agronomy Conference. 28 January–1 February 2001, Hobart, Tasmania. Australian Society of Agronomy, Hobart.

Kuiper, J. 1997. Organic mixed farms in the landscape of a brook valley. How can a co-operative of organic mixed farms contribute to ecological and aesthetic qualities of a landscape? *Agriculture, Ecosystems and Environment* 63(2–3): 121–132.

Laber, H. and Stützel, H. 2003. Ertragswirksamkeit der Restverunkrautung in Gemüsekulturen nach nichtchemischen Unkrautregulationsmaßnahmen. *Pflanzenbauwissenschaften* 7(1): 29–38.

Lampkin, N. 1990. *Organic Farming*. Ipswich, Farming Press.

Lazzari, L. and Manici, L.M. 2001. Allelopathic effect of glucosinolate–containing plant green manure on *Pythium* sp. and total fungal population in soil. *HortScience* 36(7): 1283–1289.

Leary, J. and Defrank, J. 2000. Living mulches for organic farming systems. *HortTechnology* 10(4): 692–698.

Leinonen, P. and Närkki, V. 2000. Help for the hand work on horticultural fields. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *IFOAM 2000 – The World Grows Organic. Proceedings of the 13th International IFOAM Scientific Conference*. vdf Hochschulverlag an der ETH Zurich, Basel. pp. 189.

Liebman, M. and Gallandt, E.R. 1997. Many little hammers: ecological management of crop–weed interactions. In: Jackson, L.E. (ed.) *Ecology in Agriculture*. Academic Press, San Diego. pp. 291–343.

Lukashyk, P., Berg, M. and Köpke, U. 2005. Kontrolle von *Cirsium arvense* durch Stoppelbearbeitung. In: Heß, J. and Rahmann, G. (eds) *Ende der Nische – Beiträge zur 8*. Wissenschaftstagung Ökologischer Landbau, Kassel University Press, Kassel. pp. 281–284.

MacLean, R.H., Litsinger, J.A., Moody, K., Watson, A.K. and Libetario, E.M. 2003. Impact of *Gliricidia sepium* and *Cassia spectabilis* hedgerows on weeds and insect pests of upland rice. *Agriculture, Ecosystems and Environment* 94(3): 275–288.

Mansvelt, J.D. van and Stobbelaar, D.J. (eds) 1997. Landscape values in agriculture: strategies for the improvement of sustainable production. *Agriculture, Ecosystems and Environment* 63(Special Issue): 83–250.

McCoy, S. and Parlevliet, G. (eds) 2001. *Organic Production Systems: Beef, Wheat, Grapes and Wines, Oranges and Carrots*. Rural Industries Research and Development Corporation, Barton.

Melander, B. 1998a. Economic aspects of physical intra-row weed control in seeded onions. In: Foguelman, D. and Lockeretz, W. (eds) *Organic Agriculture – the Credible Solution for the XXIst Century. Proceedings of the 12th International IFOAM Scientific Conference*. International Federation of Organic Agriculture Movements, Mar del Plata. pp. 180–185.

Melander, B. 1998b. Interactions between soil cultivation in darkness, flaming and brush weeding when used for in-row weed control in vegetables. *Biological Agriculture and Horticulture* 16(1): 1–14.

Melander, B. and Heisel, T. 2002. Prospects and limitations for agricultural engineering in the development of sustainable weed control methods – examples from European research. Paper presented at Australian Conference on Agricultural Engineering. Charles Sturt University, Wagga Wagga.

Melander, B. and Rasmussen, G. 2001. Effects of cultural methods and physical weed control on intrarow weed numbers, manual weeding and marketable yield in direct-sown leek and bulb onion. *Weed Research* 41(6): 491–508.

Merfield, C.N. 2002. *Organic Weed Management. A Practical Guide*. Charles N. Merfield, Canterbury.

Meyer, J., Buegger, F., Jensen, E.S., Schloter, M. and Heß, J. 2003. Estimating N rhizodeposition of grain legumes using a ^{15}N *in situ* stem labelling method. *Soil Biology and Biochemistry* 35: 21–28.

Milberg, P. 1997. Weed seed germination after short-term light exposure – germination rate, photon fluence response and interaction with nitrate. *Weed Research* 37(3): 157–164.

Milberg, P., Andersson, L. and Noronha, A. 1996. Seed germination after short-duration light exposure: implications for the photo-control of weeds. *Journal of Applied Ecology* 33(6): 1469–1478.

Monks, C.D., Monks, D.W., Basden, T., Selders, A., Poland, S. and Rayburn, E. 1997. Soil temperature, soil moisture, weed control, and tomato (*Lycopersicon esculentum*) response to mulching. *Weed Technology* 11(3): 561–566.

Müller, P. (ed.) 1988. *Ackerbau*. VEB Deutscher Landwirtschaftsverlag, Berlin.

Nass, H.G., IIvany, J.A. and MacLeod, J.A. 2003. Agronomic performance and quality of spring wheat and soybean cultivars under organic culture. *American Journal of Alternative Agriculture* 18(3): 164–170.

Nauta, W.J., van den Burgt, G.J. and Baars, T. 1999. Partner farms. A participatory approach to collaboration between specialised organic farms. In: Olesen, J.E., Eltun, R., Gooding, M. J., Jensen, E.S. and Köpke, U. (eds) *Designing and Testing Crop Rotations for Organic Farming – Proceedings from an International Workshop*. Danish Research Centre for Organic Farming, Tjele, pp. 149–158.

Nemming, A. 1994. Costs of flame cultivation. *Acta Horticulturae* 372: 205–212.

Ngouajio, M. and McGiffen, M.E. 2002. Going organic changes weed population dynamics. *HortTechnology* 12(4): 590–596.

Ngouajio, M. and Mennan, H. 2005. Weed populations and pickling cucumber (*Cucumis sativus*) yield under summer and winter cover crop systems. *Crop Protection* 24: 521–526.

Ngouajio, M., McGiffen, M.E. and Hutchinson, C.M. 2003. Effect of cover crop and management system on weed populations in lettuce. *Crop Protection* 22(1): 57–64.

Niemann, P. 1996. Unkrautbkämpfung durch Lichtausschluss während der Bodenbearbeitung. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz* 15: 315–324.

Niggli, U. and Dierauer, H. 2000. Unkrautbekämpfung im Ökologischen Landbau in der Schweiz. In: Pallut, B (ed.) Pflanzenschutz im Ökologischen Landbau – Probleme und Lösungsansätze – Drittes Fachgespräch am 2 Nov. 1999 in Kleinmachnow 'Unkrautregulierung im Ökologischen Landbau'. *Berichte aus der Biologischen Bundesanstalt für Land- und Forstwirtschaft* 72: 17–26.

Nucifora, A., Schiliro, E., Sortino, O., Colombo, A., Copani, V. and Cammarata, M. 1998. First results on effects of *Raphanus sativus* L. in the control of root–knot nematodes in tomato protected crops. *Atti, Giornate fitopatologiche, Scicli e Ragusa* 37: 307–312.

Oehl, F., Oberson, A., Tagmann, H.U., Besson, J.M., Dubois, D., Mäder, P., Roth, H.–R. and Frossard, E. 2002. Phosphorus budget and phosphorus availability in soils under organic and conventional farming. *Nutrient Cycling in Agroecosystems* 62(1): 25–35.

Olsen, J.K. and Gounder, R.K. 2001. Alternatives to polyethylene mulch film – a field assessment of transported materials in capsicum (*Capsicum annuum* L.). *Australian Journal of Experimental Agriculture* 41(1): 93–103.

Oomen, G.J.M. and Habets, F. 1998. Using the static whole farm model FARM and the dynamic model NDICEA to integrate arable and animal production. In: H. van Keulen, E.A. Lantinga and H.H. van Laar (eds) *Proceedings of an International Workshop on Mixed Farming Systems in Europe*. Dronten, Wageningen. pp. 199–106.

Paine, L.K. and Harrison, H. 1993. The historical roots of living mulch and related practices. *HortTechnology* 3: 137–143.

Pallut, B. 2000. Unkrautunterdrückung und -bekämpfung durch Fruchtfolgegestaltung, Bodenbearbeitung, Aussaatzeit, Saatmenge und Stickstoffversorgung. In: Pallut, B (ed.) Pflanzenschutz im Ökologischen Landbau – Probleme und Lösungsansätze – Drittes Fachgespräch am 2. Nov. 1999 in Kleinmachnow 'Unkrautregulierung im Ökologischen Landbau'. *Berichte aus der Biologischen Bundesanstalt für Land- und Forstwirtschaft* 72: 35–46.

Patriquin, D.G. 1988. Weed control in organic farming systems. In: Altieri, M.A. and Liebman, M. (eds) *Weed Management in Agroecosystems: Ecological Approaches*. CRC Press, Boca Raton. pp. 303–317.

Peacock, L. 1990. Practical constraints and opportunities for improving crop protection in organic vegetable production. In: *Crop Protection in Organic and Low Input Agriculture: Options for Reducing Agrochemical Usage*. British Crop Protection Council, Surrey. pp. 157–162.

Pekrun, C. and Claupein, W. 2004. The effect of stubble tillage and primary tillage on population dynamics of Canada thistle (*Cirsium arvense*) in organic farming. *Journal of Plant Diseases and Protection, Special Issue* 19: 483–490.

Penfold, C. 2000. *Phosphorus Management in Broadacre Organic Farming Systems*. Rural Industries Research and Development Corporation, Barton.

Penfold, C. 2001. Managing weeds organically. In: RIRDC (ed.) 2001. *The Organic Challenge: Unity Through Diversity*. RIRDC's Inaugural National Organics Conference 2001. Darling Harbour, Sydney, Australia, 27–28 August 2001. Rural Industries Research and Development Corporation, Barton. pp. 120–121.

Pfeiffer, E.E. 1970. *Weeds and What They Tell*. Bio-Dynamic Farming and Gardening Association, Kimberton.

Plagge, J. 2000. Probleme der Unkrautbekämpfung im Ökologischen Gartenbau aus Sicht der Praxis. In: Pallut, B (ed.) *Pflanzenschutz im Ökologischen Landbau – Probleme und Lösungsansätze*–Drittes Fachgespräch am 2 Nov. 1999 in Kleinmachnow 'Unkrautregulierung im Ökologischen Landbau'. *Berichte aus der Biologischen Bundesanstalt für Land– und Forstwirtschaft* 72: 14–16.

Poudel, D.D., Horwath, W.R., Mitchell, J.P. and Temple, S.R. 2001. Impacts of cropping systems on soil nitrogen storage and loss. *Agricultural Systems* 68(3): 253–268.

Pratley, J.E. 2000. Tillage and other physical management methods. In: Sindel, B. (ed.) *Australian Weed Management Systems*. R.G. and F.J. Richardson, Melbourne. pp. 105–122.

Radics, L. and Székelyné Bognár, E. 2002. Comparison of different mulching methods for weed control in organic green bean and tomato. In: Cloutier, D.C. (ed.) *Proceedings of the 5th EWRS Workshop on Physical and Cultural Weed Control*. Scuola Superiore Sant'Anna di studi universitari e di perfezionamento, Pisa, Italy. 11–13 March 2002. European Weed Research Society, Pisa. pp. 192–204.

Radics, L., Hartl, W., Gal, I., Pusztai, P., Ertsey, A. and Huspeka, C. 2003. Möglichkiten der Bekämpfung der Ackerkratzdistel (*Cirsium arvense* L.) im Ökologischen Pflanzenbau. In: Freyer, B. (ed.) *Beiträge zur 7. Wissenschaftstagung zum Ökologischen Landbau – Ökologischer Landbau der Zukunft*. Universität für Bodenkultur, Wien. pp. 528–531.

Rahkonen, J., Pietikainen, .J and Jokela, H. 1999. The effects of flame weeding on soil microbial biomass. *Biological Agriculture and Horticulture* 16(4): 363–368.

Rahmann, G., Nieberg, H., Drengemann, S., Fenneker, A., March, S. and Zurek, C. 2004. Bundesweite Erhebung und Analyse der verbreiteten Produktionsverfahren, der realisierten Vermarktungswege und der wirtschaftlichen sowie sozialen Lage ökologisch wirtschaftender Betriebe und Aufbau eines bundesweiten Praxis–Forschungs–Netzes. *Landbauforschung Völkenrode* 276: 427.

Rasmussen, I.A. 2004. The effect of sowing date, stale seedbed, row width and mechanical weed control on weeds and yields of organic winter wheat. *Weed Research* 44(1): 12–20.

Rasmussen, J. 1992. Testing harrows for mechanical control of annual weeds in agricultural crops. *Weed Research* 32: 267–274.

Rasmussen, J. 2003. Punch planting, flame weeding and stale seedbed for weed control in row crops. *Weed Research* 43(6): 393–403.

Richter, S. and Debruck, J. 2001. Einfluß der Reihenweite auf Ertrag und Qualität von Winterweizen. In: Reents, H.J. (ed.) *Beiträge zur 6. Wissenschaftstagung zum Ökologischen Landbau – von Leit-Bildern zu Leit-Linien*. Verlag Dr Köster, Berlin. pp. 233–236.

Robson, M.C., Fowler, S.M., Lampkin, N.H., Leifert, C., Leitch, M., Robinson, D., Watson, C.A. and Litterick, A.M. 2002. The agronomic and economic potential of break crops for ley/arable rotations in temperate organic agriculture. *Advances in Agronomy* 77: 369–427.

Runham, S.R., Town, S.J. and Fitzpatrick, J.C. 2000. Evaluation over four seasons of a paper mulch used for weed control in vegetables. *Acta Horticulturae* 513: 193–201.

Russo, V.M. 1992. Effects of planting date and spray-on mulch on yield of eggplant cultivars. *Journal of Sustainable Agriculture* 3(1): 41–50.

Sandhu, H.S., Wratten, S.D. and Cullen, R. 2005. Evaluating ecosystem services on farmland: a novel, experimental, 'bottom–up' approach. In: *Shaping Sustainable Systems. Proceedings of the 15th IFOAM Organic World Congress*. 20–23 September 2005 Adelaide South Australia. International Federation of Organic Agriculture Movements, Bonn.

Schäfer, W., Väisänen, J. and Pihala, M. 2001. *Technique of Green Mulch Spreading*. Agricultural Engineering Research, MTT Agrifood Research, Vakola.

Schimpf, W. and Lundberg-Schimpf, T. 2005. *Our Farm*. Flying–Two Medicinal and Aromatic Herbs, Kelowna, <http://www.bcherbs.net/ourfarm.html>. Accessed 7/5/05.

Schjønning, P., Elmholt, S., Munkholm, L.J. and Debosz, K. 2002. Soil quality aspects of humid sandy loams as influenced by organic and conventional long-term management. *Agriculture, Ecosystems and Environment* 88(3): 195–214.

Schmidt, H. and Leithold, G. 2005. Ökologischer Ackerbauversuch Gladbacherhof – Effekt von Fruchtfolge und Bodenbearbeitung in der ersten Rotation. In: Heß, J. and Rahmann, G. (eds) *Ende der Nische – Beiträge zur 8*. Wissenschaftstagung Ökologischer Landbau, Kassel University Press, Kassel. pp. 255–258.

Schonbeck, M., Stephen, H., DeGregorio, R., Mangan, F., Guillard, K., Sideman, E., Herbst, J. and Jaye, R. 1993. Cover cropping systems for brassicas in the Northeastern United States: 1. Cover crop and vegetable yields, nutrients and soil conditions. *Journal of Sustainable Agriculture* 3: 105–132.

Scopel, A.L., Ballare, C.L. and Radosevich, S.R. 1994. Photostimulation of seed germination during soil tillage. *New Phytologist* 126(1): 145–152.

Shannon, D., Sen, A.M. and Johnson, D.B. 2002. A comparative study of the microbiology of soils managed under organic and conventional regimes. *Soil Use and Management* 18(3 [Supplement]): 274–283.

Shepherd, M.A., Harrison, R. and Webb, J. 2002. Managing soil organic matter – implications for soil structure on organic farms. *Soil Use and Management* 18(3 [Supplement]): 284–292.

Sheppard, A.W. 2000. Weed ecology and population dynamics. In: Sindel, B.M. (ed.) *Australian Weed Management Systems*. R.G. and F.J. Richardson, Melbourne. pp. 39–60.

Smith, B.J., Kirkegaard, J.A. and Howe, G.N. 2004a. Impacts of Brassica break crops on soil biology and yield of following wheat crops. *Australian Journal of Agricultural Research* 55(1): 1–11.

Smith, D.R., Gilliam, C.H., Edwards, J.H., Eakes, D.J. and Williams, J.D. 1997. Recycled waste paper as a landscape mulch. *Journal of Environmental Horticulture* 15(4): 191–196.

Smith, E.G., Clapperton, M.J. and Blackshaw, R.E. 2004b. Profitability and risk of organic production systems in the northern Great Plains. *American Journal of Alternative Agriculture* 19(3): 152–158.

Stapleton, J.J., Molinar, R.H., Lynn-Patterson, K., McFeeters, S.K. and Shrestha, A. 2005. Soil solarization provides weed control for limited-resource and organic growers in warmer climates. *California Agriculture* 59: 284–289.

Stein-Bachinger, K., Bachinger, J. and Schmitt, L. 2004. *Nährstoffmanagement im Ökologischen Landbau – ein Handbuch für Beratung und Praxis*. KTBL, Darmstadt.

Stobbelaar, D.J. and Mansvelt, J.D. van (eds) 2000. Criteria for sustainable landscape development. *Agriculture, Ecosystems and Environment* 77(Special Issue): 1–175.

Stockdale, E.A., Shepherd, M.A., Fortune, S. and Cuttle, S.P. 2002. Soil fertility in organic farming systems – fundamentally different? *Soil Use and Management* 18(3 [Supplement]): 301–308.

Storeheier, K.J. 1994. Basic investigations into flaming for weed control. *Acta Horticulturae* 372: 195–204.

Stute, J. 1996. Erlaubt ist, was dem Boden nützt. *Bioland* 3: 13–14.

Sutton, B.G. 1998. *Sustainable Horticulture using in situ Mulches*. Rural Industries Research and Development Corporation, Barton, ACT.

TangYa, Yan-Zhou, Z., Jia-sui, X and Hui, S. 2003. Incorporation of mulberry in contour hedgerows to increase overall benefits: a case study from Ningnan County, Sichuan Province, China. *Agricultural Systems* 76(2): 775–785.

Teasdale, J.R. 1998. Cover plants, smother plants, and weed management. In: Hatfield, J.L., Buhler, D.D. and Stewart, B.A. (eds) *Integrated Weed and Soil Management*. Ann Arbour Press, Chelsea. pp. 247–270.

Teasdale, J.R. and Mohler, C.L. 1993. Light transmittance, soil temperature, and soil moisture under residue of hairy vetch and rye. *Agronomy Journal* 85(3): 673–680.

Theunissen, J. 1997. Application of intercropping in organic agriculture. *Biological Agriculture and Horticulture* 15(1–4): 251–259.

Tillett, N. and Home, M. 2002. Cultivations at hoeing depth. In: Welsh, J.P., Tillett, N., Home, M. and King, J.A. (eds) *A Review of Knowledge. Inter-Row Hoeing and its Associated Agronomy in Organic Cereal and Pulse Crops*. Elm Farm Research Centre, Newbury. pp. 33–50.

Tilman, E.A., Tilman, D., Crawley, M.J. and Johnston, A.E. 1999. Biological weed control via nutrient competition. Potassium limitation of dandelions. *Ecological Applications* 9(1): 103–111.

van Delden, A., Schroder, J.J., Kropff, M.J., Grashoff, C. and Booij, R. 2003. Simulated potato yield, and crop and soil nitrogen dynamics under different organic nitrogen management strategies in The Netherlands. *Agriculture, Ecosystems and Environment* 96(1–3): 77–95.

van Elzakker, B. and Caldas, T. 1999. Organic cotton production. In: Meyers, D. and Stolton, S. (eds) 1999. *Organic Cotton. From Field to Final Product*. Intermediate Technology Publications, London. pp. 21–35.

Vandermeer, J. 1989. *The Ecology of Intercropping*. Cambridge University Press, Cambridge.

Vanhala, P., Kurstjens, D., Ascrad, J., Bertram, A., Cloutier, D.C., Mead, A., Raffaeli, M. and Rasmussen, J. 2004. *Guidelines for Pphysical Weed Control Research. Flame Weeding, Weed Harrowing and Intra-row Cultivation*. *Proceedings of the 6th EWRS Workshop on Physical and Cultural Weed Control, Lillehammer*. pp. 194–225.

Vere, D.T. and Holst, P.J. 1979. The economics of using goats to control *Rubus fruticosus*. In: Medd, R.W. and Auld, B.A. (eds) *Proceedings of the 7th Asian–Pacific Weed Science Society Conference*. Sydney, Australia. 26–30November 1979. Council of Australian Weed Science Societies for the Asian-Pacific Weed Science Society, Sydney. pp. 207–209.

Vereijken, J.F.H.M., van Gelder, T. and Baars, T. 1997. Nature and landscape development on organic farms. *Agriculture, Ecosystems and Environment* 63(2–3): 201–220.

Verschwele, A. 2005. Unkrautregulierung mit Herbiziden – Chancen und Risiken für den Ökologischen Landbau. In: Heß, J. and Rahmann, G. (eds) *Ende der Nische – Beiträge zur 8*. Wissenschaftstagung Ökologischer Landbau, Kassel University Press, Kassel. pp. 291–294.

Walter, A.M., Chistensen, S. and Simmelsgaard, S.E. 2002. Spatial correlation between weed species densities and soil properties. *Weed Research* 42(1): 26–38.

Walters, C. 1996. *Weeds. Control Without Poisons*. Acres USA, Metairie.

Walz, E. 1999. *Final Results of the Third Biennial National Organic Farmers' Survey*. Santa Cruz, Organic Farming Research Foundation.

Watson, C.A., Bengtsson, H., Ebbesvik, M., Løes, A.K., Myrbeck, A., Salomon, E., Schroder, J. and Stockdale, E.A. 2002. A review of farm-scale nutrient budgets for organic farms as a tool for management of soil fertility. *Soil Use and Management* 18(3 [Supplement]): 264–273.

Whitten, G. 1999. *Herbal Harvest*. Bloomings Books, Hawthorn.

Wijnands, F.G. 1999. Crop rotation in organic farming – theory and practice. In: Olesen, J.E., Eltun, R., Gooding, M.J., Jensen, E.S. and Köpke, U. (eds) *Designing and Testing Crop Rotations for Organic Farming – Proceedings from an International Workshop*. Danish Research Centre for Organic Farming, Tjele, pp. 21–35.

Wilkie, J. and Plane, M. 2000. *Wheel Hoes – A Complete Tool System for Larger Areas*. Gundaroo Tiller. Gundaroo. <http://www.allsun.com.au/WheelHoes.html>. Accessed 19/12/05.

Willer, H. and Yussefi, M. (eds) 2005. *The World of Organic Agriculture 2005 – Statistics and Emerging Trends*. International Federation of Organic Agriculture Movements, Bonn.

Wivstad, M., Bath, B., Ramert, B. and Eklind, Y. 2003. Legumes as a nutrient source for Iceberg lettuce (*Lactuca sativa crispa*). *Acta Agriculturae Scandinavica Section B, Soil and Plant Science* 53(2): 69–76.

Women in Development Service (FAO) 2001. Agricultural implements used by women farmers in Africa. Findings of a study conducted in 1998. *SD Dimensions*. July.

Zimmerman, R. 2002. *Investigating the Impact of Green Manures and Weed Mat on Soil Biota and Tree Growth in Organic Peach Tree Orchards*. Western Colorado Research Center, Hotchkiss, Colorado.

Zinati, G.M. 2002. Transition from conventional to organic farming systems. II. Summary of discussion session and recommendations for future research. *HortTechnology* 12(4): 611–612.

Special topic 1

Developing no-tillage systems without chemicals: the best of both worlds?

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Introduction

While demand for organic produce is high, growers throughout the world face a potentially serious dilemma. Although most organic producers are concerned with soil quality including the physical, chemical and biological properties of soils, they generally use multiple inversion tillage operations (ploughing, disking, cultivation) for seedbed preparation, incorporation of cover crops and weed management. These practices can degrade soil quality. Labour and input costs in organic systems are often high because organic growers cannot use low-cost chemicals to control weeds and supply nutrients (Berry *et al*. 2002, Walz 2004). In addition, because of reliance on inversion tillage, organic farms can suffer greater soil losses than chemical-based no-till systems (Bruulsema *et al*. 2003).

Organic high-residue reduced-till systems

High-residue reduced-till systems (HRRT) offer great potential to resolve the soil quality/high tillage cost dilemma associated with organic farming (Bàrberi 2002). Ideally, HRRT is an integral part of an holistic approach to organic farm management that generates both short-term productivity and profitability and long-term production capacity (sustainability). An ideal organic HRRT system can simultaneously provide:

1. synchrony of nutrient supply with crop demand; and
2. multiple non-nutrient effects, including weed suppression, soil aggregation, resistance to erosion, biological pest management, and water infiltration and availability (Berry *et al*. 2002, Magdoff and Weil 2004).

Based on grower experiences and research data, the core components of HRRT for organic growers are:

1. regular use of grass and legume cover crop mixtures;
2. permanent soil coverage with either dead or preferably living plant residues – derived from diverse rotations of cash crops and high-residue cover crops; and
3. strategic limited number of soil disturbance events (tillage with a purpose), employed to manage weeds, regulate rate of decomposition of organic substrates and optimise soil tilth and plant establishment.

The purpose of tillage always needs to be to achieve an economic balance between the short-term need for seasonal crop productivity and the long-term need for sustaining production capacity, specifically, maintenance or enhancement of active soil organic matter (SOM) and its attendant (emergent) soil quality attributes (Schjønning *et al*. 2004).

Cover crops – their uses in organic agriculture

Production and appropriate management of high-residue cover crops are considered essential for profitable organic cropping systems. Cover crops, whether grass, legume or mixtures, are non-cash crops used to perform or achieve different objectives. When sown soon after cash crops, cover crops minimise soil erosion and absorb (capture) residual nutrients and water. Thus, cover crops perform as catch or scavenger plants to protect the environment from pollution and improve soil quality by providing important food reserves and habitat for beneficial organisms (Magdoff and Weil 2004).

Many cover crops are commonly referred to as smother crops, since they are established in high-density plantings, grow rapidly and inhibit (smother) weed growth. Generally, cover crops are grown and killed before planting cash crops. In this usage mode, they can be incorporated as green manure or killed and used as a dead mulch in no-till systems (Barker and Bhowmik 2001).

Cover crops that are interseeded and coexist with cash crops during all or a portion of the growing season are called living mulches. For organic growers, an ideal living mulch does not interfere with growth and yield of the cash crop, is low-growing, easily established and maintained by non-chemical means, and serves as a good habitat for beneficial insects. Living mulches are particularly effective with fast-growing cash crops that are supplied supplemental water and nutrients through in-row drip irrigation systems (Brandsaeter *et al*. 1998).

Specialised flowering and high nectar cover crop mixtures are grown as companion or farmscape plantings in field margins or are arranged in rows or patches at regular intervals throughout the field. Ideally, farmscape plantings contain perennial and/or reseeding annual species that smother weeds, protect the environment, build soil quality and serve as habitat and refuge for beneficial insects (Dufour 2000).

Organic no tillage – oxymoron or opportunity?

Effective integration of high-residue cover-cropping practices and no-till systems have many well acknowledged advantages:

1 conservation of soil and water;
2 moderation of soil temperatures;
3 suppression of weed and pest growth;
4 improved efficiency of nutrient use, especially nitrogen; and
5 preservation and build-up of active SOM, which is the principle soil constituent responsible for generating soil quality (Magdoff and Weil 2004).

In concept, integration of organic cropping systems with no-till practices is a logical step or progression toward improved crop yields and soil quality (Bàrberi 2002, Schjønning *et al*. 2004).

At one extreme, some growers and researchers believe organic no tillage is an oxymoron, maintaining that chemical herbicides are essential to kill cover crops and control weed growth (Lessiter 2003). However, others have shown that agronomic crops (Derpsch and Grooms 2002) and vegetable crops (Creamer *et al*. 1996, Morse 2000, Ngouajio *et al*. 2003, Madden *et al*. 2004) can be successfully grown using high-residue cover crops that were effectively killed by mechanical methods such as flail mowing or rolling. Those involved with organic no-till systems realise that, although feasible in a limited short-term scenario, permanent organic no-till systems present unique challenges because fewer weed management options are available in organic no tillage, compared to chemical no tillage. Thus, using permanent no-till systems for production of organic crops is considered a long-term, but obtainable goal (Schjønning *et al*. 2004, Trewavas 2004).

Organic no-till systems present many challenges, including production and management of high-residue cover crops, establishment of cash crops and weed management. Each challenge is discussed below with desired objectives, recommendations for success, and limitations.

Production of high-residue cover crops

Objective

To produce uniformly distributed high-residue (≥6 t ha^{-1} biomass), grass–legume cover crop mixtures on permanent controlled-traffic raised beds, keeping the soil continuously covered using diverse rotations of cash and cover crops.

Recommendations

Proper erection of wide raised beds (1.5–2.0 m wide and 0.15–0.25 m high) will help alleviate existing compaction, especially if organic-approved soil amendments (compost, manure, lime, gypsum) are thoroughly mixed deep into the soil profile during bed establishment. If wheel traffic is restricted to alleyways between beds, the integrity of bed tops can be maintained and the soil quality improved over time by growing high-residue cover crops, applying soil amendments and rebuilding bed margins as needed. Weed seedbanks can be reduced and soil quality improved over 3–6 years, if judicious weed seed sanitation and tillage practices are consistently followed (Bond and Grundy 2001, Teasdale *et al*. 2004).

Limitations

Keeping the soil permanently covered with dead and/or living residues requires timely and effective plant establishment and application of growth inputs (water and nutrients). Uniform dense cover crop stands are achieved most effectively using modern no-till seed drills (Morse 1999). Inexperience with seed drills and their high cost are often serious constraints for organic farmers, especially small-scale (1–2 ha) growers. Although labour intensive, drilling small plots with push seeders is a highly effective method of establishing cover crops (R. Morse and M.W. Schonbeck unpublished data, 2005).

Residue management

Objective

To mechanically kill cover crops, generating either:

1 a thick uniform dead mulch over the entire bed (bed tops, alleyways); or
2 a strip-killed mulch on bed tops and a non-competing living mulch in alleyways between beds.

Recommendations

Complete killing of cover crops (either the entire bed or just bed tops) is generally essential to avoid competition with cash crops. Implements used to kill cover crops include flail mowers, undercutters, rollers or roller-crimpers (Creamer and Dabney 2002).

Limitations

Incomplete kill and subsequent regrowth of cover crops can be major problems for organic growers. Unavailability and inexperience with mechanical-kill equipment are major constraints for many organic growers. Even when using appropriate equipment, cover crop regrowth can be a serious weed problem, necessitating that remedial weed-management measures be performed to minimise weed–crop competition. Mowing off cover crop regrowth with a flail mower, weed whip or scythe, or applying caustic organic materials such as acetic acid have been effective in some instances in keeping regrowth to an acceptable level (R. Morse unpublished data, 2001–2005).

Establishment of cash crops

Objective

To effectively establish seeds or transplants in high-residue mulch, with minimum disturbance of surface residue or surface soil.

Recommendations

Normally, a short fallow or waiting period of 2–3 weeks is recommended after killing cover crops to verify the effectiveness of the kill methods used and allow time for allelochemicals (natural toxins that interfere with biological processes such as seed germination and plant growth) to dissipate from killed residues before planting cash crops. After the appropriate waiting or interim pre-plant period, precision place seeds or transplants using proven no-till equipment. Commercially available one-pass no-till seeders and transplanters would be the choice for large-scale organic farms or farmer cooperatives. These one-pass no-till implements slice the organic mulch, loosen a narrow in-row strip, precision-place fertiliser, and plant with minimum residue or soil disturbance (Morse 1999).

Limitations

For small-scale farms, both residue management and plant establishment present challenges because existing available no-till equipment is expensive and small-size (1- or 2-row model) versions are normally unavailable. Although challenging, small-scale farmers can adopt no-till practices by using multiple field passes with simplified equipment to slice organic surface mulch, loosen in-row soil, precision-place organic fertilisers, and plant. Development of affordable small-scale no-till equipment is underway to facilitate adoption of high-residue no-till systems by small growers (R. Morse unpublished data, 2005).

Weed suppression

Objective

To reduce weed seedbank using year-round integrated weed management practices; and minimise early season weed growth (i.e. weed growth during the minimum weed-free period (MWFP), normally 4–6 weeks after planting).

Recommendation

Use integrated weed management strategies, emphasising permanent soil coverage, diverse rotations of cover crops and cash crops, and reduced soil disturbance (i.e. employing no-till or, at most, non-inversion tillage practices). Preventing weed seed production is an important cultural practice for organic growers, and is considered essential for organic producers who are exploring no-till systems. Roguing out escaped weeds by hand, using high-residue cultivators or elevated mowers can prevent weed seed production. Roguing to achieve a no seed threshold (NST) is highly recommended for many invasive weed species (Norris 1999). Also, using cultural practices that promote rapid plant growth and canopy closure of cash crops will result in improved weed suppression (Morse 1999). Recommended cultural practices include:

1 using vigorous seeds and transplants;
2 planting in high-density multiple rows; and
3 precision placement and timing of fertiliser and water.

Excessively weedy fields (especially those containing perennial weeds) should be cleaned up before attempting organic no-till systems. Growing successive smother crops and/or employing stale seedbed techniques for 1–2 years before attempting organic no tillage will often pay great dividends with future cash crops (Bond and Grundy 2001).

Limitations

Maintaining weeds below yield-limiting levels without using chemical herbicides or cultivation is extremely difficult. Under ideal conditions, weed suppression and an acceptable balance between crop yields and production capacity (sustainability) can be maintained or even enhanced in organic no-till systems. However, in less than ideal conditions, levels of weed seeds and/or perennating parts (tubers, bulbs, rhizomes, stolons) may be sufficiently high and cover crop biomass may be sufficiently low that the potential for early season weed growth warrants use of remedial non-inversion tillage weed implements and techniques to prevent crop yield loss (Teasdale *et al.* 2004).

Non-inversion tillage tradeoffs

Inversion tillage (ploughing) normally requires multiple field operations, resulting in excessive soil aeration, decomposition of fresh organic residues and SOM and degradation of soil structure. Rotational tillage is a trade-off or compromise between the two extremes, permanent no tillage and inversion tillage. Rotational tillage is defined here to mean the strategic sequencing of no-till and non-inversion tillage practices to achieve a balance between short-term productivity and long-term production capacity (sustainability) (Jackson *et al.* 2004). This rotational-till concept is a type of reduced tillage that calls for avoidance of inversion tillage in favour of a critical balance between no-till and non-inversion tillage practices. No-till and non-inversion tillage practices are preferred since they generate only moderate intervention in soil structure. Different types of non-inversion equipment can be used, ranging from shallow tillage with rototillers, rotary hoes, powered harrows or high-residue cultivators, to deep subsurface soil loosening with chisel ploughs or subsoiling and spading machines. Shallow (5–8 cm deep) rototilling is included in non-inversion tillage because the integrity of the subsoil layers is maintained (El Titi 2003).

When used in organic cropping systems, the objectives of non-inversion tillage are to accomplish necessary weed management, enhance short-term nutrient availability, incorporate crop residues and soil amendments, and alleviate soil compaction, with minimum soil disturbance and degradation of SOM. Ideally, non-inversion tillage is accomplished in one or two field operations. Shallow non-inversion tillage can kill cover crops and weeds and incorporate their residues 5–8 cm deep without excessive disturbance or aeration of the lower soil layers. Non-inversion in-row subsoiling (chisel ploughing) can alleviate compaction and facilitate deep placement of *in situ* crop residues and soil amendments (vertical zone mulching and soil building), thus deepening root exploration and increasing water and nutrient availability (Reetz 2000). Using permanent controlled-traffic raised beds is another aspect of rotational tillage that can create low bulk density/high tilth soil in designated plant-growing areas (grow zones) on bed tops (Magdoff and van Es 2000).

Table 1 Criteria for assessing the probability of weed suppression in organic no-till systems
C:N ratio, carbon to nitrogen ratio (weight to weight basis); minimum weed-free period (MWFP), defined as the length of time a crop needs to remain free of weeds after planting to prevent yield loss – normally, the MWFP coincides with the time of canopy closure; fertigation, when water and soluble organic fertiliser are applied in the irrigation system.

Site factor criterion	Probability of achieving weed suppression		
	Low	Moderate	High
Mulch quantity[A] – dry wt (g m^{-2})	<400	400–800	>800
– soil coverage (%)	<75	75–95	>95
– depth (cm)	<5	5–10	>10
Mulch quality – C:N ratio	<15	15–25	>25
Perennial weeds (% total weeds)	>20	2–20	<2
MWFP (canopy closure, weeks)	>6	4–6	<4
Monthly in-season rainfall (mm)	>100	40–100	<40
Fertigation method	Overhead	Furrow	Drip

[A] J.R. Teasdale, pers. comm., 2004.

When attempting to adopt organic no-till systems, a major challenge is to predict accurately the weed suppression potential of any given situation. Six criteria for assessing the probability of achieving weed suppression in organic no-till systems are presented in Table 1. Weed suppression is likely when most or all the six factors are in the medium to high probability categories (Table 1). When weed predictions reveal a low potential for weed suppression or when actual field weed excesses occur, growers may decide that remedial weed management tactics are necessary. Three common scenarios are presented in Table 2, in which predicted (using Table 1) or actual weed densities warrant remedial intervention to preserve crop yield (Barker and Bhowmik 2001).

Table 2 Remedial weed management methods recommended when predicted (using Table 1) and/or when actual weed incidence is high in organic no-till fields

Growth stage of cash crop when weeding is considered necessary	Optional weed management methods
Pre-plant (1–4 weeks before planting cash crop)	**Objective: revert to green manure, non-inversion-till systems** • flail mow, if needed, and shallow incorporate cover crops and weeds • after incorporating residues, use stale-seedbed techniques – shallow till or flame weed seedlings • apply plastic mulch • after planting, cultivate or flame weed seedlings and apply organic mulch
Early crop establishment (2–3 weeks after planting) before weed–crop competition occurs	**Objective: prevent weed-crop competition** • shallow cultivate between rows • apply acetic acid, using a shielded sprayer • hand weed in-row areas • after weeding, apply organic mulch
Rapid crop growth (3–6 weeks after planting); weed–crop competition present	**Objective: minimise crop yield loss and prevent production of weed seeds** • shallow cultivate between rows, if possible • apply acetic acid, using a shielded sprayer • rogue out large weeds by hand or use high-residue cultivators or elevated mowers

Conclusions and recommendations

Production and appropriate management of high-residue, grass–legume mixtures are highly recommended cultural practices for improving productivity and soil quality in all cropping systems: organic, chemical or integrated. Use of cover crops as green manures is a common and highly valued practice of many organic growers. Because cover crops are now being used extensively in chemical no-till systems, many proponents and some practitioners of organic agriculture believe that organic no tillage is the ideal system to achieve a desirable balance between short-term productivity (yield) and production capacity (sustainability).

The question is not whether integration of organic cropping systems with no-till practices is a sound concept, it is how to produce organic no-till cash crops without herbicides. Most growers and agricultural professionals recognise the potential immediate and emergent (synergistic long-term) benefits of organic no-till integration; unfortunately, experience has often been disappointing. Generally, however, good weed suppression and high yields are achieved in warm long-season climates where organic cash crops are effectively established in high-residue dead cover crop mulch.

Using site-specific tillage rotations (strategic sequencing of no tillage and non-inversion tillage) can help growers bridge the gap between the ideal scenario (organic no tillage, i.e. weed suppression without chemicals or tillage) and weed management problems that frequently occur in organic no-till fields. Two distinct situations are possible when organic no-till growers may revert to using non-inversion tillage implements. First, just before or after planting cash crops, a grower may determine that a remedial weed management tactic needs to be used to prevent production of weed seeds and preserve the cash crop (Tables 1 and 2). Second, after harvesting cash crops and before drilling overwintering cover crops, growers may choose to employ a single or a combination of non-inversion tillage equipment to:

1 kill residual vegetation (cash crops and weeds);
2 incorporate plant residues and applied soil amendments;
3 alleviate subsoil compaction; and
4 prepare an improved seedbed for drilling cover crops.

In the following spring or summer, overwintering cover crops could then be used as a high-residue mulch for production of organic no-till or reduced-till cash crops.

In summary, organic no-till systems are recommended only where high-residue cover crops can be grown and managed properly, and when productivity of cash crops is favourably affected by root and shoot biomass (surface residue mulch) of the cover crops. Research and grower experience have shown that organic no-till systems are most likely to succeed:

1 in warm, long-season climates, especially Mediterranean-like regions;
2 in well-drained, fertile soils, especially on sloping, erosion-prone land;
3 with late plantings, i.e. when there is not an early-season market demand;
4 when cash crops are established from transplants or large seeds; and
5 when cover crops produce high-residue levels of persistent biomass that can suppress weeds (Table 1).

Tilling only in-row areas (grow zones) and leaving the alleyways untilled and covered with sod or cover crops is an alternative ‘hybrid’ system that can be used in more challenging circumstances such as compacted soils and cold short-season climates. Depending on the site-specific situation, in-row tilled areas can be either covered with pre-plant plastic mulch or post-plant organic mulch, or left uncovered as strip-till or ridge-till (raised-bed) systems (El Titi 2003).

Future research priorities

Future research needs include development and evaluation of:

1 affordable no-till equipment (particularly roller-crimpers and other residue management implements, and no-till planting aids) for small-scale organic farmers;
2 cost-effective practices and strategies to prevent production of weed seeds and reduce weed growth during the minimum weed-free period (4–6 weeks after planting cash crops);
3 techniques and strategies to improve efficient nutrient use, especially synchrony of nitrogen supply and crop demand;
4 spatial interseeding of grass and legume cover crops on controlled-traffic raised beds to optimise both nitrogen efficiency and weed suppression; and
5 strategic crop and tillage rotations, designed to achieve a more desirable balance between high marketable crop yields and high soil quality or production capacity (sustainability).

We conclude by outlining a strip-interseeding technique that integrates list items (4) and (5) above (Chen *et al.* 2004, R. Morse and M.W. Schonbeck, unpublished data, 2004). Growing legume and grass species in alternating multiple-row zones on controlled-traffic raised beds can indeed be the best of both worlds. Winter-kill or overwintering legumes are grown on bed tops in designated zones (grow zones) where subsequent cash crops are to be grown; and overwintering high-residue grass smother crops are grown in alleyways and between grow zones on bed tops to maximise weed suppression. In the following spring or summer, cash crops are established in the nitrogen-rich grow zones, using either no-till seeders or transplanters, or non-inversion strip-till implements followed by conventional seeders or transplanters. Alleyway areas are maintained as a dead or living mulch, resulting in conservation of soil and water, suppression of weeds and creation of habitat for beneficial organisms.

References

Bàrberi, P. 2002. Weed management in organic agriculture: are we addressing the right issues? *Weed Research* 42: 177-193.

Barker, A.V. and Bhowmik, P.C. 2001. Weed control with residues in vegetable cropping systems. *Journal of Crop Production* 4: 163-183.

Berry, P.M., Sylvester-Bradley, R., Philipps, L., Hatch, D.J., Cuttle, S.P., Rayns, F.W. and Gosling, P. 2002. Is the productivity of organic farms restricted by the supply of available nitrogen? *Soil Use and Management* 18: 248-255.

Bond, W. and Grundy, A.C. 2001. Non-chemical weed management in organic farming systems. *Weed Research* 41: 383-405.

Brandsaeter, L.O., Netland, J. and Meadow, R. 1998. Yields, weeds, pests and soil nitrogen in a white cabbage-living mulch system. *Biological Agriculture and Horticulture* 16: 291-309.

Bruulsema, T.W., Dibb, D.W., Reetz, H.F. and Fixen, P.E. 2003. Productivity of organic cropping systems. *Better Crops* 87(1): 16-18.

Chen, C., Westcott, M., Neill, K., Wichman, D. and Knox, M. 2004. Row configuration and nitrogen application for barley-pea intercropping in Montana. *Agronomy Journal* 96: 1730-1738.

Creamer, N.G., Benner, M.A., Stinner, B.R. and Cardina, J. 1996. A comparison of four processing tomato production systems differing in cover crop and chemical inputs. *Journal American Society for Horticulture Science* 121: 559-568.

Creamer, N.G. and Dabney, S.M. 2002. Killing cover crops mechanically. Review of recent literature and assessment of results. *Journal of Alternative Agriculture* 17: 32-40.

Dabney, S.M., Schreiber, J.D., Rothrock, C.S. and Johnson, J.R. 1996. Cover crops affect sorghum seedling growth. *Agronomy Journal* 88: 961-970.

Derpsch, R. and Grooms, L. 2002. Why no-till is booming in South America. *No-till Farmer*. November: 12-13.

Dufour, R. 2000. *Farmscaping to Enhance Biological Control*. Appropriate Technology Transfer for Rural Areas, Fayetteville.

El Titi, A. (ed.) 2003. *Soil Tillage in Agroecosystems*. CRC Press, Boca Raton.

Jackson, L.E., Ramirez, J., Yokota, R., Fennimore, S.A., Koike, S.T., Henderson, D.M., Chaney, W.E., Calderon, F.J. and Klonsky, K. 2003. On-farm assessment of organic matter and tillage management on vegetable yield, soil, weeds, pests, and economics in California. *Agriculture Ecosystems and Environment* 103: 443-463.

Lessiter, F. 2003. Without herbicides, no-till would disappear. *No-till Farmer* July: 13.

Madden, N.M., Michell, J.P., Lanini, W.T., Cahn, M.D., Herrero, E.V., Park, S., Temple, S.R. and van Horn, M. 2004. Evaluation of conservation tillage and cover crop systems for organic processing tomato production. *HortTechnology*. 14(2): 243-250.

Magdoff, F. and van Es, H. 2000. *Building Soils for Better Crops*. Sustainable Agriculture Network, Burlington.

Magdoff, F. and Weil, R.R. 2004. *Soil Organic Matter in Sustainable Agroecosystems*. CRC Press, Boca Raton.

Morse, R.D. 1999. No-till vegetable production – its time is now. *HortTechnology* 9: 373-379.

Morse, R.D. 2000. High-residue systems for production of organic broccoli. In: Bollich, P.A. (ed.) *Proceedings of the 21st Southern Conservation Tillage Conference for Sustainable Agriculture*. Louisiana State University, Crowley. pp. 48-51.

Morse, R.D. 2001. No-herbicide, no-till summer broccoli – quantity of rye and hairy vetch mulch on weed suppression and crop yield. In: Stiegler, J.H. (ed.) *Proceedings of the 24th Southern Conservation Tillage Conference for Sustainable Agriculture. Conservation Tillage: Benefiting Farmers, Society, and the Environment, 9-11 July, 2001, Oklahoma City, Oklahoma*. Oklahoma State University, Sillwater. pp. 83-92.

Norris RF. 1999. Ecological implications of using thresholds for weed management. *Journal of Crop Management* 2(1): 31-58.

Ngouajio, M., McGiffen, M.E. and Hutchinson, C.M. 2003. Effect of cover crop and management system on weed populations in lettuce. *Crop Protection* 22: 57-64.

Reetz HF. 2000. Producing high corn yields – Herman Warsaw's challenging legacy. *Better Crops* 84(1): 20-22.

Schjønning, P., Elmholt, S. and Christensen, B.T. 2004. *Managing Soil Quality – Challenges in Modern Agriculture*. CABI Publishing, Wallingford.

Teasdale, J.R., Abdul-Baki, A.A., Mills, D.J. and Thorpe, K.W. 2004. Enhanced pest management with cover crop mulches. *Acta Horticulturae* 638: 135-140.

Trewavas A. 2004. A critical assessment of organic farming-and-food assertions with particular respect to the UK and the potential environment benefits of no-till agriculture. *Crop Protection* 23: 757-781.

Walz E. 2004. *Fourth National Organic Farmers' Survey: Sustaining Organic Farms in a Changing Organic Marketplace*. Organic Farming Research Foundation, Santa Cruz.

Chapter 4

Crop protection in organic agriculture

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Introduction

Organic farming systems are challenged by many of the same crop protection issues as conventional farming systems. Approaches to crop protection in organic agriculture differ widely among growers globally and regionally. At one end of the spectrum, organic growers use substitution-based approaches in large-scale operations to capture premium prices in a niche market. At the other end, resource-poor farmers producing subsistence crops use, by default, pest regulation tactics based on traditional knowledge. Organic growers at both ends of the spectrum are less motivated by environmental and public health considerations than are those growers that have formed the philosophical centre of organic agriculture movements in various parts of the world. For these growers, organic agriculture differs fundamentally from conventional agriculture, not in terms of the pest and disease challenges that face crop production or solely in the range of tactics used by growers, but in the conceptual approaches that frame crop management strategies.

Too often, descriptions of the conceptual approaches in conventional and organic agriculture are overly simplified (Trewavas 2004). Conventional pest control can no longer be characterised as the reliance on scheduled applications of broad-spectrum pesticides (biocides, insecticides, fungicides, herbicides). Best practices in conventional agriculture incorporate a wide range of tactics, including pest monitoring and judicious use and timing of selective pesticides, selection of insect and disease-resistant cultivars, and cultural controls such as crop rotation and crop residue destruction. By the same token, organic agriculture is more than conventional agriculture minus synthetic fertiliser and pesticide inputs. While some organic growers do simply substitute manure for fertiliser and botanically derived pesticides for synthetic pesticides – more often, organic practices involve a wide range of soil management and cropping practices that maintain ecosystem health and foster ecosystem services (Altieri 1986 1999, van Bruggen and Semenov 2000).

For the purpose of this chapter on pest and disease management, organic agriculture is defined as plant and animal production systems managed with an emphasis on sustainable and renewable biological processes: nutrients supplied at rates needed to maintain nutrient balances through decomposition of nitrogen (N)-fixing green manures and plant or animal-based soil amendments, and pest management relying heavily on promoting plant health, vegetation management and biological control. Curative pest treatments include application of microbials, botanicals, soaps, oils and minerals and augmentative releases of predators; synthetic fertilisers or pesticides are generally not applied, unless exemptions are granted.

We will use a theoretical approach to the characterisation of pests and diseases in agricultural systems, based on some of the ideas from invasion ecology. Invasion ecology is a complex and dynamic intellectual conversation often focused on exotic plants, mammals and birds. Here, we don't consider only exotic species as invaders but also any pathogen or pest species not yet present in a crop in a particular growing season. To apply some basic concepts of invasion ecology to crop protection, we consider three phases of invasion:

1 colonisation
2 establishment, and
3 population outbreak.

We explore whether certain invasion trends may be distinguished for herbivorous arthropods, nematodes, fungi, and bacteria in organic versus conventional farming systems. By borrowing the term *invasibility*, we can examine how organically managed crops may present barriers against the invasion by pests and pathogens, and compare them, when possible, with conventionally managed crops. In natural ecosystems, low invasibility has often been related to high biodiversity depending on the scale of observation (Peterson *et al.* 1998), and this relationship may also hold for managed agroecosystems (Knops *et al.* 1999). Organically managed agroecosystems are generally more diverse than their conventional counterparts. This has been shown for above-ground natural plant and crop species, insects and birds, as well as for below-ground arthropods, nematodes, fungi and bacteria (e.g. Mäder *et al.* 2002, Aude *et al.* 2004, Asteraki *et al.* 2004, Oehl *et al.* 2004). The reasons for this difference in biodiversity are manifold, but in particular, the:

1 absence of herbicides reduces detrimental effects on various microbial species;
2 absence of synthetic nematicides and insecticides reduces broad-spectrum effects on beneficial fauna;
3 absence of general fumigants reduces broad-spectrum activity on all soil life;
4 absence of easily available plant nutrients reduces the selective enhancement of fast-growing microorganisms, and
5 addition of various plant and animal-derived organic materials enhances the soil food web and, indirectly, the above-ground food web.

In addition, organic farmers frequently purposefully plant strips of controlled natural vegetation, which affects not only above-ground biodiversity, but also soil biodiversity. If higher biodiversity in agroecosystems reduces invasibility, then we can expect a reduced spread of pests and diseases in organic compared to conventional farms. We suggest that this expectation is largely met, but that there are exceptions.

We compare the range of pests and diseases that challenge crop productivity in organic and conventional farming systems around the world. Our emphasis here is on arthropod pests and diseases, but we include some observations on vertebrate and other invertebrate pests. We then describe organic and conventional strategies for pest and disease management, including the three elements:

1 prevention of colonisation or establishment;
2 population regulation through biological processes; and
3 curative interventions.

To illustrate these elements of pest and disease management in practice, we critically review comparative research programs on conventional and organic pest control in many parts of the world, and illustrate the constraints and opportunities of organic crop protection under different farming conditions. We conclude by providing suggestions on future research directions that will advance our knowledge and capacity for effective crop protection in organic agriculture.

Pests and diseases in organic versus conventional agriculture

Pests and diseases that plague conventional farming operations, causing yield loss or the application of costly inputs, are often the same species that challenge organic growers producing the same crops. One significant difference is that organic growers avoid the use of broad-spectrum synthetic pesticides, which severely disrupt natural controls in the system and promote the occurrence of secondary pests (Johnson and Tabashnik 1999). Well-known secondary pests in pesticide intensive systems include spider mites in temperate orchards treated for codling moth, rice brown planthopper in pesticide-treated tropical paddy rice, *Rhizoctonia* black scurf in potato after nematicide applications that reduce fungi-feeding collembola (Hofman 1988), and apple scab as a result of decimation of earthworm populations by the fungicide benomyl (slowing down decomposition of infected leaves). A substantial number of major pests in conventional systems, then, are regulated at low levels in organic systems by virtue of the conservation of their natural enemy complex.

Natural pest and pathogen controls are not only conserved (not disrupted) but are also promoted in organic farming conditions. Most soilborne plant pathogens causing root and foot rots in older plants are usually less prevalent in organic than in conventional farms (van Bruggen and Termorshuizen 2003). This kind of disease suppression has frequently been associated with higher microbial activity and diversity, with higher microfaunal numbers and diversity, and/or with lower soil and crop N concentrations in organic than in conventional soils. Attacks by some airborne diseases (in particular many powdery mildew and rust diseases) and by sucking insect pests (aphids and whiteflies) can also be less severe in organic than in conventional crops due to lower nitrogen concentrations in foliar tissues or phloem on organic than on conventional farms (van Bruggen 1995).

Some arthropods are favoured under conditions of organic farming practices, however, particularly below-ground pests that are fostered by rich organic matter such as the garden symphylan, cutworms, wireworms (Jansson and Lecrone 1991, Peachey *et al.* 2002) and slugs or hardy pest insects that have few biological controls and are not effectively controlled with allowable organic inputs such as the strawberry weevil or *Lygus* bug. Similarly, damping-off causing pathogens such as *Pythium* species can wreak havoc in organic crops, since these can multiply quickly in fresh organic materials incorporated into soil (van Bruggen 1995). Certain foliar diseases that can spread quickly and are controlled by frequent fungicide sprays in conventional farms, such as potato late blight and onion downy mildew, can be devastating on organic crops in humid climates (Piorr and Hindorf 1986, van Bruggen 1995). Stored products pests should also be a particularly challenging problem for organic agriculture, since synthetic insecticides are prohibited. However, it seems that stored products pests are a universal problem posing challenges for conventional and organic farmers alike. Haines (2000) describes many problems with synthetic chemical approaches in the past decades to long-term storage pest control, and proposes new innovations in alternative control strategies. These control strategies include those used by organic growers (Table 4.1).

Vertebrate pests, such as deer and other ungulates, fruit-eating and seed-eating birds, rodents, rabbits and squirrels colonise or intermittently visit both organic and conventional farms, potentially reducing yields and/or affecting food quality. Some of the practices more common on organic farms such as cover cropping, farmscaping with non-crop vegetation, and mixed cropping encourage beneficial fauna and repel some vertebrate pests, but may also improve the habitat for other vertebrates, such as gophers, voles and noxious birds. Organic practices overlap with those of conventional farming for control of these pests, including

Table 4.1 Relative reliance on different crop protection practices in organic and conventional agriculture to reduce crop invasion by pests and pathogens
Examples of specific practices are included in Altieri 1989, Lampkin 1999, Gliessman 2001, Litterick *et al.* 2004, van Bruggen 1995.

Invasion stage/ approach	Specific practices	Organic	Conventional
Colonisation prevention			
Sanitation	Pathogen-free seed, debris destruction, flaming, steaming (fumigation in conventional farming)	Common	Common
Temporal asynchrony	Late or early planting or harvest with respect to pathogen, vector or pest arrivals	Common	Common
Inconducive conditions	Crop rotation, repellent cultivars, soil suppressiveness by organic amendments, temperature control and repellents in storage facilities and greenhouses	Common	Common
Synthetic chemical barrier	preventive foliar sprays with synthetic insecticides, nematicides, acaricides, anticoagulants, fumigants, fungicides or bactericides; botanical pesticides containing petroleum derivatives	Absent	Common
Spatial isolation	Crops sown distant from pest or pathogen hosts, weeds, non-crop hosts removed, barrier crops or natural strips, physically distant from all coloniser pools	Occasional	Rare
Disrupt colonisers	Mating confusion, trap cropping, sterile male releases, and low voltage 'soft electrons' for insects, fences, trapping, netting for birds and mammals, sealant, reflective tape and startling sound for birds and rodents	Occasional	Occasional
Population regulation			
Host plant resistance	Suboptimal plant quality (low fertilisation), resistant cultivars, crop spacing, plant extracts or other repellents or hormones applied to stored products	Common	Common
Genetically modified resistance	Genetically modified crops with *Bacillus thuringiensis* toxins, proteinase inhibitors, various forms of resistance against diseases	Absent	Common in some countries
Intercropping	Mixed cultivars, mixed cropping, strip cropping, green manures, incorporation of repellent plants	Common	Occasional
Competition	Enhanced herbivore and microbial diversity to reduce the proportional representation of injurious taxa	Common	Rare
Insectary vegetation or predator resources	Flowering plants in field margins, strips, islands, hedgerows, cover crops, bat and owl nesting sites, bird perches to attract and retain natural enemies in the crop field	Common	Occasional

Invasion stage/ approach	Specific practices	Organic	Conventional
Conservation	Avoid use of biocides that disrupt natural enemies and competitors	Common	Occasional
Unsuitable environment	Ventilation, humidity, and temperature control (greenhouses and storage facilities), humidity control by irrigation, irradiation	Common	Common
Curatives[A] (at population level)			
Synthetic pesticides	Various systemic and contact insecticides, molluscicides, acaricides and fungicides, pyrethroids	Absent Exceptional	Common Common
Organics	Soaps, oils, compost teas	Common	Rare
Inorganics	Sulfur dust and sprays, diatomaceous earth, micronutrients (Si or Zn), iron phosphate, CO_2, N_2, copper hydroxide, Bordeaux mixture	Common In some countries	Common
Botanicals	Plant extracts without petroleum-based synergists (pyrethrum, rotenone, nicotine, neem, horsetail)	Rare	Rare
Inundative biological control	Predators (e.g. ladybirds, predatory mites), parasitoids (e.g. egg parasitoids, larval parasitic wasps and flies), bacteria (e.g. *Bacillus thuringiensis, B. subtilis*), entomopathic and nematopathic fungi (e.g. *Entomophthora, Trichoderma, Beauveria* and *Verticillium*), viruses (e.g. arboviruses)	Occasional[B]	Occasional
Physical removal	Trapping, vacuuming, handpicking, hunting	Occasional	Rare

[A] In the plant pathology literature, only systemic fungicides with kick-back action are considered curative, but here, we include any pesticides that limit further spread of pests and diseases in the plant population. [B] Provided no petroleum-based synergists or carriers are used.

sanitation, exclusion, trapping and the use of a variety of repellents (visual, vegetation management, auditory) but exclude the use of many fumigants, anticoagulants and toxins.

Organic growers may therefore expect to encounter most of the same pests and pathogens as conventional growers in their fields. However, the dynamics of these organisms depend on the extent to which the organism's resource requirements are met and degree to which natural controls are functioning in the management system. Therefore, for many pests and pathogens, organic practices reduce the probability of establishment and spread in the crop field despite the presence of the same crop host. For other pests and pathogens, organic practices promote suitable conditions for population growth, resulting in particular challenges for growers with limited agrochemical options.

Pest and disease management in organic versus conventional agriculture

Crop protection in organic agriculture is accomplished through three general approaches, by:

1 preventing colonisation by pests and pathogens;
2 regulating the abundance of pests and pathogens at low levels through biological processes; and
3 employing curatives that are allowed under organic agriculture guidelines.

The first two approaches tend to be prophylactic control measures and the latter involves the substitution of synthetic chemical inputs used in conventional crops once pest or disease levels begin to rise. Because prophylactic crop protection in organic systems is based on ecological processes, the crop is seen as a host, the crop field and surroundings as a biotic community with its abiotic conditions, and the pest or pathogen as an invader that colonises the crop habitat, establishes and erupts. Barriers to pest outbreaks include various means of isolating the crop from pest/pathogen source pools and regulating pest and pathogen populations once established through community resistance (Table 4.1). Community resistance comprises those factors that cause the habitat to be unsuitable for proliferation of invaders, such as resource limitation, competition, and predation. Community resistance compensates for synthetic pesticides in conventional agriculture (Drinkwater *et al.* 1995, Lampkin 1999). Above-ground, community resistance involves the conservation and enhancement of beneficial fauna, either directly or via diversified vegetation. In soil, community resistance can be enhanced by activation of the soil food web through amendment with slowly decomposing organic materials. Enhancement of biodiversity is the key element in these efforts. Curative measures, taken as pest or pathogen populations begin to rise, include application of organically approved biocides or behaviour-modifying compounds derived from natural sources or inundative releases of other organisms (competitors, predators, or parasites). Curative measures may substitute for synthetic pesticides in conventional agriculture (Guthman 2000), and can complement other tactics, such as biodiversity enhancement. Successful crop protection in organic systems relies on prophylactic measures that prevent pest and pathogen colonisation, establishment or build up sometimes in combination with curative measures when needed.

Prevention of colonisation or establishment of pests and pathogens in organic agriculture

Colonisation of the crop field, orchard, vineyard, storage facility or other agricultural environment by pests and pathogens is prevented through sanitation, source isolation, and other protective measures. Practices to prevent colonisation and establishment of pests and pathogens, namely sanitation, clean seeds or vegetative propagating materials, crop rotation, adjustment of planting time, removal of certain weeds, fencing or netting against vertebrates, sealing or repelling against storage pests, hold for both organic and conventional agriculture. However, they are even more important for organic farming, because curative measures are restricted here. The use of various crop protection practices to prevent colonisation of the crop by pests and pathogens are at least as common in organic agriculture as in conventional agriculture (Table 4.1). To illustrate some of the particular problems facing organic growers, we consider seed sanitation and crop rotation.

EU regulation 2092/91 for organic farming requires that all inputs in organic agriculture, including seeds and vegetative materials, must originate from the organic production chain when available (Lammerts van Bueren *et al.* 2003). Officially registered seeds and vegetative material must be true to type, pure and healthy (in terms of percentage germination and freedom from plant pathogens and pests). It is sometimes assumed that seed produced under organic conditions would have a greater 'vitality' than conventionally produced seed, but there is no scientific evidence for this assumption. It is more likely that the germination and emergence capacity of seeds is primarily determined by the pathogens that become associated with the seeds in the seed production phase and during seed storage. In conventional seed production firms, seed samples are tested for pathogen infection, and infected seed batches are culled so that seeds can be marketed as certified disease-free, but organic seeds are (still) frequently produced in small companies that lack those facilities. Thus, organic growers may face problems with seed-borne diseases as long as inspection of organic seed is less stringent than that in conventional seed production (see *Chapter 5*).

Pathogens and pests can also be avoided by adapting the crop planting time or rotating crops that harbour different suites of pests and pathogens (temporal isolation). The time between rotations of a particular crop is usually longer in organic than conventional field crop production (5–8 years v. 2–3 years). Successive planting of the same crop is not permitted according to organic standards in the EU, but rotation times are minimised in organic greenhouse production as only high value crops with similar cultural practices can be grown such as tomato, sweet pepper and cucumber in rotation. Organic growers practicing short crop rotations in greenhouses can face severe problems with root knot nematodes in soil-bound production of these high-value crops.

Organic growers can avoid diseases and pests by planting susceptible crops at times of the year when certain pests are less pervasive. For example, to avoid severe damage from late blight, organic farmers plant early maturing potato varieties early in the growing season so that tubers have grown to a reasonable size by the time late blight becomes pervasive (Tamm *et al.* 1999). Asynchrony of dispersing insect pests and susceptible crop stages is a tactic used commonly by organic and conventional growers worldwide. For example, winter wheat production in the northern US can be timed to avoid infestation by Hessian fly (*Mayetiola destructor*), which lives as an adult for only a few days. The US Department of Agriculture provides estimates of fly-free dates for growers sowing varieties that are otherwise susceptible to the pest. Subsistence farmers in Malawi avoid devastation of their bean crop by sowing with the first rain. Later crops are attacked heavily by bean fly (e.g. *Ophiomyia spencerella*), which can kill the plant. Planting crops before peak aphid vector flights can reduce virus infection in US lettuce production. The next generation of aphids is often wingless and is less likely to move between plants. Planting dates can also be used to reduce vertebrate pest damage, such as January plantings of sunflower crops in India, planned to reduce the synchrony of sprouting plants and mature seeds with the incidence of harmful birds (house crows and rose-ringed parakeets) (Mahli 2000).

Invasion biology and metapopulation theory claim that organisms can be prevented from spreading into patchy islands when the distance between patches is large. Therefore, crop fields can be isolated from source pools by keeping large distances between fields with the same crop. In northern California, organic production of kiwi fruits is successful in part because of sparse cultivation of this specialty crop. In organic agriculture with longer rotations, the patch sizes (fields with a certain crop) are frequently smaller than in conventional agriculture. Moreover, fields are often separated by strips of natural vegetation on organic farms. Thus, crop plants can be pathogen-free and herbivore-free as a consequence of locating fields distant from coloniser pools (Letourneau 1999). However, small-scale organic farmers cannot always take advantage of this method to avoid pests and diseases, since all plots may be located very close together. For example, fields on some small-scale organic farms are organised as 'pie-pieces' in a circle, where all crops shift to the next small 'pie-piece' in the following season. Although this circular arrangement is appealing to customers who buy produce at the farm, risks of pest and disease problems are enhanced through movement of pathogens and pests from plant residues to neighbouring seedlings of the same species. Finally, the source pool itself can be removed by destroying weeds that act as carriers or alternate hosts of crop pests and pathogens. Weeds and natural vegetation surrounding cropping areas may harbour various diseases, particularly viral and bacterial diseases (Thresh 1982, Wenneker *et al.* 1999). Also, poplar trees may harbour lettuce root aphids, which move to adjacent lettuce crops (Phillips *et al.* 1999). On the other hand, non-crop vegetation can host various parasitoids and predators that contribute to insect pest control (Barbosa 1998, Pickett and Bugg 1998), and a judicious approach to weed control is needed. Many organic farmers remove weeds selectively and maintain natural surroundings carefully to avoid the spread of pests and diseases into their crops.

Storage pests are a particularly difficult problem; although storage facilities are often patchy, pests and pathogens tend to either move with the produce from the crop field to the storage facility or reside in the storage facility, making isolation difficult for many pest taxa in both organic and conventional farming operations.

Regulation of established pests and pathogens in organic agriculture

Once a pest or pathogen becomes established in a crop, field or storage facility various processes act to either enhance its abundance and spread in the system (invasion occurs) or to suppress its abundance and spread (persistence at low levels). These processes involve either host or product quality or the presence of suppressive agents in the community that regulate population growth of the pathogen or pest in the crop environment. In addition, physical impedance to spread by enhanced distances between hosts or physical barriers contributes to pest and pathogen regulation. Host plant quality can be optimised for minimal disease severity or reduced success of herbivorous insects (Scriber 1984). Indeed, crop resistance to pests and pathogens is a mainstay of organic agriculture. Resistance to pest and pathogen exploitation is brought about by selecting varieties with genetically based resistance traits, managing the phenotype, health and nutrient concentration to reduce its suitability for pests and pathogens, or managing crop and non-crop vegetation to reduce the concentration of food plants for herbivores (see *Community resistance*). Suppressive agents include competitors (neutral herbivores and microbes avirulent or less damaging to the crop) and natural enemies (predators and parasitoids of the pestiferous and pathogenic organisms). Included in this arsenal of crop defences are tactics that can be used together to protect the crop from yield loss either in the field or in the storage facility (Table 4.1). Integrative strategies are a cornerstone of successful crop protection in organic agriculture. In the following sections we explore the tactics available in organic agriculture, their effectiveness and limitations.

Host plant resistance

Host plant quality is optimised for crop protection when:

1 adequate nutrient status for plant productivity and health is maintained, without excess nutrients or imbalances that support high levels of herbivores or pathogens; and
2 toxic or repellent properties are sufficient to directly reduce pest or pathogen exploitation and survival.

The first approach is somewhat flexible, allowing for a grower to respond to pest and pathogen dynamics. However, the decision to use a resistant variety is set for the season. Its use will be determined by the probability of invasion, the severity of the pest or pathogen, any associated loss of yield quality or quantity, marketability, complementarity with other crop protection tactics, and the effectiveness of the resistant cultivar against the target and other possible exploiters. A caveat to these generalisations is that ‘one organism’s famine is another organism’s feast’, that is, very high nitrogen may attract an insect and deter a plant parasitic nematode (if ammonia is released from the nitrogen source). High mustard oil content deters insects that find it toxic, and attracts those that specialise on mustard family crops.

Depending on the target pests or pathogens, plant quality-based resistance can be induced by regulating the type and quantity of nutrients and moisture applied to the crop. For example, high N levels can enhance the population growth of certain aphids, but when potassium (K) is in ample supply, the amount of soluble N circulating in the phloem tissue is reduced, thus retarding aphid fecundity (van Emden 1966). Water shortage, in contrast, accelerates the breakdown and mobilisation of proteins and enriches the phloem nutrient quality for aphids, whereas excess moisture may predispose the crop to root-rotting pathogens. Sometimes nutrient sources used by organic growers can produce mineral balances that reduce the suitability of crop plants for pests and vectors, such as European corn borer (Phelan 1997) or the bean fly (Letourneau and Msuku 1992, Letourneau 1994). Thus, management practices can enhance or reduce host plant resistance by regulating the quality of food source for insects or pathogens (but see Letourneau 1997). Likewise, certain physiological conditions increase the incidence and severity of disease, and can be mitigated by management practices. For example, high N concentrations in soil and plant tissues may predispose a crop to diseases like powdery mildew, rust and certain root-rotting pathogens (Daamen *et al.* 1989, Tamis and van den Brink 1998). However, shortages of some elements may also enhance the susceptibility to certain diseases; for example, K shortages increase the risk of *Verticillium* wilt in cotton, and calcium (Ca) shortages enhance susceptibility to *Pythium* root rot (Engelhard 1989).

Inherently resistant cultivars have been available for many crops, providing resistance against diseases caused by fungi, bacteria, viruses and nematodes as well as certain insect pests. The mechanisms underlying the resistance range from physical features such as tough leaves, and hairy or waxy tissues to deterrent or toxic secondary plant compounds in the foliage, fruits or seeds. Some of the resistance features have a broad activity against many pests and diseases and are based on multiple genes. For example, leaf toughness forms a significant impediment to insect herbivore feeding and pathogen ingression on many crops (Bergvinson *et al.* 1994, Agrios 1997). Alkaloids such as nicotine, glucosinolates and cyanogenic glycosides, found in tobacco, cabbage and cassava respectively, are not only toxic to most herbivores but also to many plant pathogens (Rosenthal and Janzen 1979, Agrios 1997). The inhibiting agents can be present continuously (constitutive resistance) or can be induced by stress, insect feeding or infection by pathogens and symbionts.

If a single gene governs resistance to pest exploitation, a cascade of biochemical reactions is usually triggered by a particular elicitor of a pathogen or pest, resulting in strong resistance. In many cases a pathogen or pest population can adapt relatively easily to this kind of resistance through heavy selection pressure (Riggs 1959), while counter-resistance is not so easily selected against multiple, mild resistance factors. For this reason, organic growers prefer to use plant cultivars and animal breeds with broad resistance based on multiple genes (see *Chapters 5* and *6*). Although this means that a limited level of infection or feeding may occur, organic growers take this for granted, since they value a greater genetic variation and the associated yield stability. For the same reason, many organic growers prefer open-pollinated varieties over hybrids. Moreover, mild resistance based on multiple genes can still be effective, when combined with other tactics such as biological control of pests, pathogens or vectors, even when it is insufficient to control a pathogen or pest on its own (Wyss *et al.* 2001, Vaarst *et al.* 2003).

Plant resistance traits may work indirectly through their effects on natural enemies. For example, certain maize plants (*Zea mays*), when fed upon by caterpillars, release a mixture of volatile compounds that attract parasitic wasps. Varieties known to produce these induced odour emissions will likely maximise biological control by being particularly attractive to parasitoids (e.g. Degen *et al.* 2004). Varietal selection for maximum effectiveness for biological control is in its infancy, and is often targeted for the discovery of gene sequences that can be transferred to conventional cultivars. The production of varieties particularly suited to organic production systems is progressing in recent years, but the choices are limited compared to varieties for conventional conditions (Jahn 2003, see *Chapter 5*).

Community resistance – vegetation

A key characteristic of natural plant populations is their genetic and phenotypic heterogeneity. Individual plants tend to occur in natural habitats displaying a mosaic of resistance levels due to genetic variability (Whitham and Slobodchikoff 1981) and induced responses. Such heterogeneity inherently reduces the probability of counter-resistance in rapidly evolving pathogens and phytophagous arthropods, and increases the durability of plant defences over time. A mixed cropping or mixed varietal scheme reduces the concentration of suitable food plants for insects and pathogens that specialise on a subset of the plants or varieties grown in the mixture (Finckh 1997, Mundt 2002). Herbivores, particularly specialised feeders, have a lower probability of finding their host plant under these conditions, and tend to leave the field at greater rates than when suitable hosts are concentrated in monocultures. However, the searching efficiency of parasitoids may also be reduced (Bukovinszky 2004), while indirect effects through plant quality and emission of volatiles may also have a role in the effects of crop mixtures on herbivore suppression (Bukovinszky *et al.* 2004). Spread of plant pathogens is inhibited by resistant components in the mixture forming obstacles and traps. Andow's (1983, 1991) reviews of the literature on pest population densities in mixed cropping versus monoculture showed that 56% of the herbivores had lower population densities, 16% had higher population densities, and 28% had similar or variable densities in polyculture compared to monoculture. Intercropping is an integral part of many low-input, traditional cropping systems in the tropics, but is only occasionally used for products destined for the organic market, especially in temperate regions.

Community resistance – pathogens and herbivores

The degree to which competition among herbivores or among microbes ultimately reduces plant injury in natural systems is debated. In agroecosystems, where the reduction of target pest numbers is often the goal, it is conceivable that the guilds of plant exploiters could be shifted to include more neutral invaders and prevent the build up of the few most injurious species. Theoretically, organic practices that promote the richness of plant-supported microbes and herbivores in the community can cause such a 'dilution effect' of the pestiferous taxa, thus reducing crop injury levels and yield loss. However, innovative practices aimed at specific taxa have not always been successful. For example, supplemental feeding of rodents aimed at increasing the numbers of competing, non-pestiferous species in Canada did not reduce vole densities or damage (Sullivan and Sullivan 2004).

Community resistance – biological control

Organic crop production relies on the suppression of pathogens and pests through the introduction, conservation or enhancement, or augmentation of predators (or parasitoids). Natural biological controls of pests and pathogens are enhanced in organic systems that foster and maintain biodiversity through limited use of disruptive curatives coupled with vegetation management (Barbosa 1998). Plants growing within and near the crop field offer resources for natural enemies such as alternate prey or hosts, pollen or nectar, as well as microhabitats that are not available in weed-free monocultures (Letourneau and Altieri 1999) or extensive cropping operations with little non-crop vegetation. Non-crop vegetation serves to increase faunal biodiversity, which increases the potential for ecosystem services to growers. Because organic growers tend to rely more on ecosystem services for crop health than do growers employing chemical input intensive schemes, vegetation management and farmscaping have become key crop protection tools in some areas. The challenge is to encourage natural enemies without overly favouring pest organisms. Detailed knowledge of animal behaviour, resource use and movement patterns with respect to non-crop vegetation can aid in vegetation management schemes for biological control and biodiversity conservation. For example, studies of bird communities in riparian strips in Quebec suggested that woody vegetation increased richness of some insectivorous birds, but did not increase pestiferous red-winged blackbird densities in adjacent crop fields (Deschenes *et al.* 2003). Microbial communities in organically managed soils are often highly diverse compared to simpler systems managed with low vegetational diversity and synthetic chemical inputs. Consequently, plant pathogens are frequently suppressed in organic farming systems by enhanced microbial complexity and activity, brought about by regular soil amendment with recalcitrant organic materials like mature composts and manure (Mäder *et al*. 2002, van Bruggen and Termorshuizen 2003, Litterick *et al*. 2004).

Curative control

There are limited options for curative control allowed under organic agriculture guidelines, which vary from country to country. Curatives are inputs to the crop production system that are applied after a pest or pathogen has established in the crop, and threatens to reduce yields if action is not taken. Table 4.1 provides a representative list of botanically derived pesticides, microbial agents and other naturally available materials typically approved under organic standards. These materials vary in their toxicity levels and non-target effects.

In many countries, copper fungicides are allowed for persistent problems such as the control of late blight on potatoes and downy mildew on grapes. Similarly, sulfur fungicides are used to control powdery mildew on various crops and scab (*Venturia inaequalis*) on apples and pears. The number of sulfur sprays may even exceed that of synthetic fungicides in conventional apple production, but the environmental impact may still be lower (Spruijt-Verkerke *et al*. 2004). The environmental impact of copper can be significant, considering the broad impact spectrum and the tendency to accumulate in soil. Finally, some synthetically produced curatives, such as pyrethroids, are allowed for certain uses as an exception to the rule. However, the organic regulations are adjusted constantly, and curative applications are becoming more restricted. For example, copper fungicides are already banned in many countries.

Various plant extracts are allowed under most organic guidelines, provided that they are not formulated in petroleum-based synergists or carriers. However, they are only rarely used, primarily as insecticides (Table 4.1). Compost extracts are used more frequently, and are commercially formulated these days (Litterick *et al*. 2004). They can be very effective in disease control, depending on the starting material, the composting and fermentation procedures, and the final microbial activity.

Curative biological control can be accomplished by inundative release of selected biocontrol agents. Although many specific biological control agents against plant pathogens, insect and nematode pests have been identified, relatively few species have been registered for field use, primarily parasitoids and predators for insect and mite control, and some fungi and bacteria for insect and pathogen control. Biocontrol of soilborne pathogens has been successful under controlled environmental conditions using simplified potting mixes, but has often failed when selected microorganisms were added to field soil (Fravel 1999). This is also the case, even more so, for foliar microbial biocontrol agents due to the increased exposure to the elements. We recently noticed that the bacterial biocontrol agent *Pseudomonas fluorescens* did not survive as well in organically as in conventionally managed soil (Hiddink *et al*. 2005). It may be more difficult to get a biocontrol agent established in a microbially diverse organic soil than in a microbially impoverished conventional soil, as could be expected from invasion biology theory.

One might expect that organic growers would use biological control proportionally more than conventional growers, but surveys indicate that biological control agents are rarely applied on organic farms (Langer 1995), with the exception of *Bacillus thuringiensis* (Bt) for caterpillar control and various parasitoids and predators in greenhouse production. In most countries, organic regulations allow the application of biological control agents, provided that no petroleum-based synergists or carriers are used in the formulation. It is possible that the greater biodiversity in organic agroecosystems (in the open air) reduces the effectiveness of inundative biological control agents through intraguild predation or competition.

Pest and disease management case studies in organic versus conventional agriculture

Relatively few replicated, on-farm studies compare the relative effectiveness of organic and conventional crop protection practices. This is particularly true for vertebrate pests. Table 4.2 lists recent examples of field comparisons between organic and conventional agriculture in different crops and location. These studies show that biodiversity is generally higher on organic farms, that pests and pathogens are usually regulated by organic practices, but that there are exceptions in either case. Few studies monitor pest levels and related yield losses. Even fewer studies are integrative for crop protection, monitoring both pests and pathogens. We provide two detailed, integrative case studies selected from European agriculture and commercial operations in the western USA to illustrate some constraints and benefits of organic agriculture practices. These examples and those listed in Table 4.2 illustrate many of the general themes described above, including:

1 holistic approaches that characterise organic agriculture;
2 the kinds of pests and pathogens affected by different management practices;
3 the possibility of different, but equally successful, routes to crop protection; and
4 the importance of diversity in promoting ecosystem services for organic agriculture.

Table 4.2 Recent on-farm and field-experiment comparisons of pest or disease levels under organic or ecological versus conventional management

Crop	Management practices in organic crops	Crop protection consequences as compared to conventional	Reference
Almond	A mixed cover crop, no fertilisers or pesticides	Shot hole disease more severe, almond scab on leaves and fruits similar; no differences in fungal communities	Teviotdale and Hendricks (1994)
Apple	Organic soil amendments that promote soil microbial diversity	Higher growth scores and lower colonisation by root pathogens (*Pythium* sp., *Rhizoctonia solani*)	Manici *et al.* (2003)
	Organic soil amendments that promote soil microbial diversity	Less *Pythium* root rot, more non-pathogenic *Pythium* spp.	Mazzola *et al.* (2002)
	Sulfur sprays	More severe apple scab (*Venturia inaequalis*), similar orange tortrix (*Argyrotaenia citrana)*	Vossen *et al.* (1994)
	Weed-, disease-, nutrient management	Lower abundances of predaceous beetles, lower diversity of non-predaceous beetles	Pearsall and Walde (1995)
Carrot	Biological pest control, soil management	Higher diversity of predaceous arthropods	Berry *et al.* (1996)
Cereals (wheat, barley, triticale, rye)	Organic practices (lower fertility, no pesticides)	No difference in epigeic collembolan composition	Alvarez *et al.* (2001)
		No difference in species richness of butterflies, rove beetles, spiders, lower richness of carabids	Weibull *et al.* (2003)

Crop	Management practices in organic crops	Crop protection consequences as compared to conventional	Reference
Cereals (wheat, barley, triticale, rye)	Organic practices (lower fertility, no pesticides)	Lower densities of aphids, higher densities of weevils, leaf beetles, spiders, plant hoppers, plant bugs and sawfly larvae	Moreby and Sotherton (1997)
		Lower infection with ear blight (*Fusarium* spp.) and lower mycotoxin contamination	Birzele *et al.* (2002)
	Organic practices (lower fertility, no pesticides)	Reduced incidence and severity of foot rots and root rots, eyespot, and take-all; similar or less powdery mildew (*E. graminis*); similar, less or more leaf spot and glume blotch (*S. nodorum*); similar or more leaf rust (*Puccinia* spp.); less stripe rust (*P. striiformis*); less leaf blotch (*M. graminicola*)	Various authors cited in van Bruggen and Termorshuizen (2003) (root diseases) and in van Bruggen (1995) (root and shoot diseases)
	Organic with red clover as pre-crop	Higher numbers of total predators	Basedow (1991)
	Organic experimental fields, sulfur applications	More severe *Septoria* leaf blight at end of season; more severe powdery mildew at beginning of season	Higginbotham (1996)
Grape	Organic management; cover crops	No difference in *Phylloxera*, but reduced severity of secondary fungal root infections	Lotter *et al.* (1999)
Maize	Organic management, winter cover crops, composted chicken manure	Aphids, mites and corn ear worm fluctuated from year to year, but were similar in organic and conventional field plots; more seed corn maggot in 1 of 8 years	Clark *et al.* (1998)
Olive	No synthetic pesticides	Low mortality and higher fecundity of lacewing adults	Corrales and Campos (2004)
Pepper	Organic management, compost, cover crop	Corn borer (*Ostrinia nubilalis*) larval populations similar, beneficial insect populations greater in 1 year; fruit damage by insects or diseases less or similar	Delate *et al.* (2003)
Potato	Absence of fungicides or only copper fungicides	Much more severe late blight (*Phytophthora infestans*)	Piorr and Hindorf (1986), Zwankhuizen *et al.* (1998)
Rice	Ecological agriculture practices	Similar or higher arthropod abundance, with no decrease in yield	Hossain *et al.* (2002)
	Organic practices	Similar abundance of major pests, damage and species richness of arthropods	Hesler *et al.* (1993)
Straw-berry	Organic, no insecticides	Higher tarnished plant bug density and damage	Rhainds *et al.* (2002)
	Mulch, no fumigation	*Cylindrocarpon* root rot greater in organic	Rosado-May *et al.* (1994)

Crop	Management practices in organic crops	Crop protection consequences as compared to conventional	Reference
Straw-berry	Straw mulch, no fumigation or fungicides, low fertility	Less fruit rot by *Botrytis cinerea*, variable grey mould severity depending on cultural practices	Gliessman *et al.* (1996), Daugaard (1999)
Tea	No synthetic pesticides	Greater abundance and diversity of carabid beetles	Mukhopadhyay *et al.* (2003)
Tomato	Biological insecticides and living mulch	Higher level of thrips and caterpillar damage.	Hummel *et al.* (2002)
	Cover crops, composted manure, insecticidal soap, Bt	Same levels of potato aphids, army worm and tomato fruit worm, wild fluctuations; more stinkbug injury in 1 of 8 years	Clark *et al.* (1998)
		Lower severity of corky root, *Fusarium* and *Pythium* root rot, *Phytophthora* root rot	Clark *et al.* (1998), Workneh *et al.* (1993)
		Reduced Southern blight	Bulluck and Ristaino (2002)
	Organic, cannery waste compost	Reduced anthracnose (*Colletotrichum coccodes*) on fruits	Abbasi *et al.* (2002)
Various crops	Alternative soil amendments	Higher *Trichoderma* and lower *Phytophthora* and *Pythium* propagule densities	Bulluck *et al.* (2002)
	Organic practices, habitat diversification	Higher species richness, abundance and activity of nocturnal insects insectivorous bats	Wickramasinghe *et al.* (2003)
	Organic management: cover crops, composted chicken manure	Reduced populations of *Pratylenchus* spp., *Rhizoctonia solani* and *Verticillium dahliae* in soil	Clark *et al.* (1998), Berkelmans *et al.* (2003), Neher and Olson (1999), van Bruggen and Termorshuizen (2003)
	Biodynamic mixed farm with 6 years grass-clover in a 10 year rotation	Carabid abundance and species richness generally higher (except in potato) Staphylinid and spider abundance and species richness generally similar	Booij and Noorlander (1992)
	Organic practices	Greater abundance and lower diversity of predaceous beetles	Shah *et al.* (2003)

Case study 1 – pest and pathogen regulation in organic versus conventional cereal crops in Europe

Since the 1980s, the proportion of cereal crops (wheat, barley, oats, rye) has steadily dropped in conventional agriculture in north-western Europe (except for France). The main reason is a reduction in price supports, resulting in such low prices that it is not profitable to grow cereals as intensively as was commonly done in this region (with straw shorteners, high fertilisation, and frequent fungicide and insecticide applications). On organic farms, cereal crops are still profitable as they are grown less intensively. Moreover, they are essential crops in the longer rotation schemes. Some of these crops (oats, rye, triticale) are also used as winter cover crops to reduce nitrate leaching. Because of the large differences in production practices for cereal crops at organic versus conventional farms in Europe, many comparative studies of farming systems have focused on these crops. Most comparisons have involved single (experimental) farms side by side (Rabbinge and Zadoks 1989). In a few cases, replicated experimental treatments were compared (Hannukala and Tapio 1990), and even fewer publications covered large surveys on many farms (Tamis and van den Brink 1998 1999).

From all these studies it is apparent that fungal root and foot rots caused by *Fusarium* species are similar or reduced in organic cereal crops. The same holds for take-all disease caused by *Gaeumannomyces graminis* and for eyespot and sharp eyespot caused by *Pseudocercosporella herpotrichoides* and *Rhizoctonia cerealis*, respectively (van Bruggen 1995). In some studies, the lower disease levels at organic farms were associated with lower N application rates (van Bruggen and Termorshuizen 2003), higher microbial activity and diversity (Hiddink *et al*. 2005), or greater populations and/or diversity of soil microfauna (Mäder *et al*. 2002, van Bruggen 1995). Another reason for suppression of root diseases in organic cereal crops could be enhanced competition by arbuscular mycorrhizae, which are generally more abundant in organic than in conventional crops, due to the lower available N and P in organically managed soils (Oehl *et al*. 2004).

The lower N application levels in organic cropping systems also have a tremendous influence on above-ground diseases and pests. Powdery mildew, snow mould and stripe rust of wheat were less severe in a long-term organic than in a neighbouring conventional experimental farm in the Netherlands, despite regular fungicide applications in the conventional system (Daamen *et al*. 1989). This was attributed to lower N levels in the organic wheat tissue, but could also be due to a more open canopy structure and less conducive microclimate. In an extensive survey of 150 Dutch wheat fields, most above-ground diseases (snow mould, powdery mildew, *Septoria* leaf and glume blotch, *Fusarium* scab) were less severe in the organic than in the conventional and integrated farming systems (Tamis and van den Brink 1998). The differences were significant for snow mould, glume blotch, and *Fusarium* scab. Contrary to the two-farm study mentioned above (Daamen *et al*. 1989), there was no significant difference for stripe rust, while leaf rust and powdery mildew on the ear were significantly more severe in organic than in conventional farms (Tamis and van den Brink 1998). Incidences of diseases that were higher in conventional farms than in organic farms were again positively correlated with N application rates (Tamis and van den Brink 1998). The higher severity of leaf rust and powdery mildew on the ears of organic than on those of conventional wheat plants may also have been related to N concentrations, since N is released from soil organic matter in the summer time, and can be higher in organic than in conventional farms at that time.

Plants high in N can also support large aphid populations (van Emden 1966, Thresh 1982) and are often more susceptible to virus infection. Thus, when high soil nitrate concentrations coincide with aphid flights, the population may grow explosively. Unfortunately, organic farmers have little control over the time when N is released in soil, and in some seasons aphid populations may be as high in organic as in conventional farming systems (Daamen *et al*. 1989, Piorr and Hindorf 1986). Leaf miners and cereal leaf beetles were generally more numerous in the conventional farming system and were associated with high N application rates (Daamen *et al*. 1989). In an extensive field survey, no significant differences were found in populations of aphids, leaf miners and cereal leaf beetles between organic and conventional farms, but there were enormous variations among years (Tamis and van den Brink 1998). Nevertheless, it is important to try to keep mineral N concentrations minimal, also at organic farms. This can be done by focusing on organic matter build up over many years, and minimising applications of additional organic fertilisers during crop growth.

The absence of fungicide use in organic cereal production has given rise to concerns about grain moulds and mycotoxins on organic cereals. These concerns are not always justified. *Fusarium* scab of wheat was less severe in organic than in conventional farms in the Netherlands (Tamis and van den Brink 1998). In several German studies, *Fusarium* contamination of grains and concentrations of deoxynivalenol (DON) were also lower in organic than in conventional farms (Birzele *et al.* 2002, Schollenberger 2002), while in some French studies *Fusarium* head blight severity and mycotoxin levels were similar in organic and conventional wheat production (Champeil *et al.* 2004). DON concentrations were also similar in organic and conventional grains in a British study (Berlath *et al.* 1998), but were below the European threshold level. Average levels of ochratoxin A contamination (from *Penicillium* and *Aspergillus*) were similar in rye and barley grains from organic and conventional farms, but significantly lower in organic than in conventional wheat grains (Czerwiecki *et al.* 2002). Thus, there is no reason to believe that mycotoxins would constitute a problem in organic cereal products (Schollenberger *et al.* 1999). The main reason for lower contamination levels at some organic farms may be the lower N contents and greater diversity of non-pathogenic fungi on the ears of unsprayed plants (Lemmens *et al.* 2004). Moreover, mycotoxin production per unit mycelium can be enhanced by the stress of certain fungicides (Felix D'Mello *et al.* 1998).

Insect pests can often be kept in check by a greater diversity of non-herbivorous arthropods. Piorr and Hindorf (1986) noticed an increase in beneficial insects during the conversion period on a biodynamic farm. Reddersen (1997) also observed a higher diversity of arthropods in organic cereal fields, accompanied by a lower arthropod abundance compared to conventional cereal fields. In many other studies, a relatively high arthropod abundance in organic compared to conventional wheat fields was associated with a higher arthropod diversity in organic wheat fields (Moreby *et al.* 1994, Basedow 1995, Pfiffner and Niggli 1996). Feber *et al.* (1997) measured similar levels of pest butterflies in organic versus conventional farmland, but found significantly more non-pest butterflies in organic farmland. Total numbers of epigeic predatory arthropods were also highest in organic farming systems compared to pesticide intensive agricultural production systems (Basedow 1991). Among epigeic predators, carabid abundance and species richness were higher in organic cereal fields, while staphylinid and spider abundance and species richness were generally similar in different management systems (Booij and Noorlander 1992). The reasons for the frequently greater arthropod diversity in organic farms can be found in the greater variety of food sources associated with greater plant diversity within fields and in surrounding habitats (Booij and Noorlander 1992, Holland and Fahrig 2000, Asteraki *et al.* 2004).

Greater plant diversity in the field can also have benefits for disease control in cereal crops. Different cereal crops, for example barley and wheat, have sometimes been grown in mixtures resulting in a reduction in barley powdery mildew by increasing the distance between susceptible plants (Burdon and Whitbread 1979). However, mixtures of wheat and field beans resulted in higher powdery mildew severity on the wheat crop as the bean density increased (Bulson *et al.* 1997); this was probably as a result of the greater N content of the wheat plants. Cultivar mixtures with different resistance genes have also been very effective in controlling different barley powdery mildew pathotypes (Finckh *et al.* 2000). The use of cultivar mixtures was a very effective and widespread practice in the former Eastern Germany (Finckh *et al.* 2000) and is now practiced on a large scale in rice production in China. Unfortunately, organic growers have not yet widely adopted this practice. Another form of mixed cropping, relay cropping of clover between cereal plant rows, is gaining popularity in Europe. This practice helps control weeds, supplies N to the next crop, and contributes to disease control, particularly of take-all caused by *Gaeumannomyces graminis* (G.A. Hiddink, A.J. Termorshuizen, J.M. Raaijmakers and A.H.C. van Bruggen, unpublished data).

Thus, organic practices that promote biodiversity both above ground and below ground tend to enhance the resilience of the arable farming system so that many pests and diseases are controlled by natural enemies. These practices include an extensive rotation, soil organic matter management fostering high turnover rates and relatively low residual mineral nutrients with minimal fluctuations, crop or cultivar mixtures, and varied field margins. Although this is a desirable scenario for cereal production, it is not always practiced, and the great variation in organic farming practices understandably results in large variations in pest and disease intensities.

Case study 2 – pest and pathogen regulation in organic versus conventional tomato fields in California

Tomato is a relatively high input crop in Californian agriculture. Of the top 15 vegetable crops, 11 field crops, and 11 fruit or nut crops produced in the USA, Pimentel *et al.* (1981) listed tomato as having the highest percentage of acreage treated with insecticides (93%) and fungicides (98%) and the ninth highest for acreage treated with herbicides (67%). A 36% yield reduction was predicted if pesticides (insecticides, fungicides) were not applied to the tomato crop (Agricultural Issues Center 1988). To check this premise, pests, diseases and their natural enemies were monitored in two complementary comparative studies in California. Van Bruggen participated in the Sustainable Agriculture Farming Systems (SAFS) experiment in Davis, California, where irrigated conventional, low-input and organic cropping systems with 4-year rotations were compared with a 2-year conventional rotation from 1989 through 2001 (Poudel *et al.* 2001). All crops in the rotation were represented each year, and there were four replicated blocks for a total of 56 plots on 11 ha. Tomatoes were the most intensively investigated crop species in this experiment with respect to disease incidence and severity, insect pests, weed infestations and N dynamics. Letourneau and van Bruggen carried out a two-year survey of 18 organic (ORG) and conventional (CNV) commercial tomato production systems to compare:

1 the incidence of pests and pathogens;
2 injury levels and pest damage to the crop;
3 pest abundance and disease severity;
4 biodiversity of the microbial and arthropod communities associated with the crop; and
5 nutritional status of the crop.

The survey was carried out on nine ORG and nine CNV tomato fields in a 600 km^2 area, encompassing five counties in the Central Valley of California. This sample covered a representative spectrum of actual commercial farming practices, and the variability needed to identify particular practices that affect pest management. All 18 farms used the same tomato cultivar Blazer® (Drinkwater *et al.* 1995). Farms in both ORG and CNV management categories included sites bordered by various combinations of annual crop fields, orchards, oak woodland and riparian habitats. All fields were maintained reasonably weed-free within the beds during the growing season, but annual weeds were abundant along roadsides and field edges, especially where sufficient moisture was available. The cropping history of the fields, however, was not independent of management category. Most conventional farms were maintained as bare ground fallows over winter through initial tillage and subsequent herbicide applications, whereas organically managed fields had a vegetative cover with annual weeds and/or cover crops (see Workneh *et al.* 1993, Drinkwater *et al.* 1995, Letourneau *et al.* 1996, and Letourneau and Goldstein 2001 for details of sites, design and sampling methods).

Root disease incidence and microbial community structure

In both the experimental study and the field surveys, foliar diseases were not important on irrigated tomatoes (mostly by furrow irrigation) in the semi-arid climate of California. Only occasionally, diseases such as bacterial spot (*Xanthomonas campestris*) occurred when it rained early in the season (Clark *et al.* 1998). Virus symptoms were also seldom observed. There were no differences in foliar disease incidence and severity between organic and conventional farming systems. Root diseases were quite common and sometimes severe in conventional tomato fields, but were absent or only slight in low-input and organic fields.

In the SAFS experiment, corky root (*Pyrenochaeta lycopersici*) was significantly more severe in the conventional system with a 2-year rotation and only slightly more severe in the conventional system with a 4-year rotation compared to the low-input and organic systems (Clark *et al.* 1998, van Bruggen and Termorshuizen 2003). The same was true for root rot caused by *Pythium aphanidermatum*. Differences in severity of other root rots were mostly not significant. These observations were made six, seven, eight and nine years after the start of the experiment. In the last two years, there were significant differences between both conventional treatments and the alternative treatments. Both alternative systems had winter cover crops, and much better water penetration than the conventional systems, which developed a hardpan over time. The organic plots had lower nitrate concentrations in soil and plant tissues and a higher microbial biomass and associated food web (particularly bacteria-feeding nematodes) than the conventional plots (Ferris *et al.* 1996). There were positive correlations between corky root severity and N concentrations in soil and plant tissues (A.H.C. van Bruggen, unpublished data, 1998).

In the field survey of tomato-producing farms in California both the incidence and severity of corky root were lower in well-established and recently converted organic farms (ORG) than in conventional farms (CNV). The main variables explaining corky root incidence and severity levels were N concentrations in both soil and tomato tissue (Workneh *et al.* 1993). Corky root was more numerous and severe at higher N concentrations. However, N mineralisation potential and fluorescein diacetate (FDA) hydrolysis, both measures of microbial activity, were negatively correlated with disease severity. These relationships were confirmed in greenhouse experiments (Workneh and van Bruggen 1994a). In other greenhouse and laboratory experiments, corky root suppression in ORG soils was associated with larger populations and higher diversity of actinomycetes in the rhizosphere (,Workneh and van Bruggen 1994b, Drinkwater *et al.* 1995). The community composition of actinomycetes and bacteria were more similar among samples with the same soil management (CNV or ORG) than between different management types (CNV v. ORG). Phytophthora root rot (*Phytophthora parasitica*) was also more severe in CNV than ORG fields, but this difference was primarily associated with soil texture, structure and moisture content instead of microbial and nutritional factors (Workneh *et al.* 1993).

Plant-parasitic nematode populations, in particular *Pratylenchus* spp., were significantly lower in the organic and low-input systems than in the conventional systems of the SAFS experiment as early as 1993, four years after initiation of the experiment. This difference was maintained until the end of the experiment in 2000 (Ferris *et al.* 1996, Clark *et al.* 1998, Berkelmans *et al.* 2003). Populations of *Meloidogyne* spp. were not consistently lower in the alternative systems than in the conventional systems (Clark *et al.* 1998, Berkelmans *et al.* 2003). Root knot symptoms on tomatoes were rare and differences were not consistent among treatments (Clark *et al.* 1998). Bacterivorous nematodes were generally more abundant in the organic and low-input than in the conventional treatments (Ferris *et al.* 1996). Accordingly, the enrichment index, a measure of resource availability, was higher, and the channel index, a measure of domination of the fungi-based over the bacteria-based food web, was lower in the organic and low-input than in the conventional treatments (Berkelmans *et al.* 2003). Moreover, the structure index, a measure of the number of trophic layers and potential for regulation of opportunists, was generally higher in the organic and low-input than in the conventional systems (Berkelmans *et al.* 2003). Suppression of *Meloidogyne javanica* in a bioassay was negatively correlated with the channel index, indicating that suppression was associated with a bacteria-dominated food web as observed in the organic and low-input plots of the SAFS experiment (Berkelmans *et al.* 2003). A positive correlation between suppression of *M. javanica* and microbial biomass had been described earlier (Jaffee *et al.* 1998). At that time, no relationship was found between *M. javanica* suppression and management system, nor with total number of nematode trapping fungi, yet the diversity of nematode trapping fungi was greater in the organic plots (Jaffee *et al.* 1998).

Thus, the general tendency was that root infections by fungal pathogens and populations of plant parasitic nematodes were lower in organic than in conventional soils, and this was associated with either higher microbial diversity and activity, and/or a better soil structure, and/or a more complex soil food web in the organic soils. These characteristics are typical for a healthy soil that can resist disturbances by invading species (van Bruggen and Semenov 2000). Such a healthy soil is attained by organic practices such as winter cover cropping, applications of compost, and avoidance of synthetic pesticides and fertilisers.

Pest incidence, tomato injury and arthropod community structure

In the SAFS experiment, arthropod pests were monitored every two weeks by taking plant and fruit samples. Pest populations fluctuated significantly from year to year. Russet mites were occasionally problematic, and were treated with sulfur in all fields in the first few years (Clark *et al.* 1998). Potato aphids, armyworm and tomato fruit worms were severe enough to warrant insecticide sprays in the conventional treatments. Insecticidal soap and Bt were occasionally applied in the organic treatment. These were less effective than synthetic insecticides, so that aphid and armyworm populations were sometimes higher in organic plots, but in general, insect pests did not differ significantly among management treatments. The lack of significant differences among treatments was attributed to the relatively small plot size (0.11 ha per plot), necessitating an extensive on-farm field survey (Clark *et al.* 1998).

In the field surveys, arthropods were vacuum extracted from tomato foliage. The major tomato pests, such as thrips, aphids, tomato russet mite, flea beetles, leaf-eating caterpillars, leafminers, fruit-eating caterpillars and fruit-piercing insects were present in all fields. Average damage levels accruing over the season were significantly correlated with the mean abundance of the most common species of that pest group collected in vacuum samples. That is, western flower thrips *Frankliniella occidentalis* abundance was directly correlated to percent tomato leaflets damaged by thrips; flea beetle (*Epitrix hirtipennis*) abundance was positively correlated with percentage tomato leaflets damaged by pit-feeders; and tomato fruitworm (*Helicoverpa zea*) abundance and percentage of fruits with deep wounds typical of fruitworm damage were also significantly correlated.

Damage from insect pests was variable among fields and among pest groups (e.g. leaf grazers, foliage pit-feeders, fruit punctures), but the average levels of overall and specific types of damage in organic and conventional fields were not significantly different (Drinkwater *et al.* 1995, Letourneau and Goldstein 2001). The average abundance of phytophagous insects was virtually the same on organic and conventional tomato at the time of crop harvest. Although crop N levels were significantly lower in organic fields, neither pest levels nor damage was explained by tissue N levels (Letourneau *et al.* 1996).

However, community-level profiles (richness and abundance of herbivores and natural enemies) in commercial tomato fields under organic and conventional management were significantly different despite the wide range of specific farming practices and conditions represented within these management categories (Letourneau and Goldstein 2001). Organic farms had a more diverse arthropod fauna than conventional farms, with the average for five 30-s vacuum samples per farm yielding about 40 arthropod morphospecies in conventional tomato and 66 morphospecies in organically managed tomato. Natural enemies (parasitoids plus predators) were almost twice as abundant on organic compared to conventional farms.

Conventional tomato fields received seven times as many insecticide sprays as organic fields (Letourneau and Goldstein 2001), and the application frequency, spectrum of toxicity and persistence of pesticides was inversely associated with some of the prominent natural enemies. Fields managed with cover crops or annual weeds over the winter wet season had at least a magnitude higher abundance of these parasitoids and flea beetles than did fields that were kept in bare fallow (no vegetation). Vegetative fallow practices, which maintained vegetative cover during the wet season, may have perennialised the crop habitat to allow continuity of certain arthropod populations through the year. Natural enemies are often enhanced in perennial crop habitats and in vegetative fallow compared to annual crops disrupted by bare fallow (Honek 1997). However, insecticide treatments could disrupt the potential stability gained by local vegetational cover. In general, practices used more often on organic farms, such as cover cropping and low intensity pesticide treatments, were associated with increases in parasitic wasps (primary source of variability among farms) and more predators.

Clearly, the avoidance of synthetic insecticides and fungicides in organic tomato production did not reduce yields by the predicted 36% (Agricultural Issues Center 1988). Indeed, in both the SAFS experiment and the field surveys, there were no significant differences in pest damage between CNV and ORG treatments. Arthropod communities were not monitored in the SAFS experiment, but substantially different arthropod community profiles in ORG v. CNV farmers' fields (species diversity of herbivores and abundance and species diversity of natural enemies) suggested that natural biological control on ORG farms may be compensating for pesticide inputs in CNV operations. Whereas specific management practices and landscape characteristics of ORG and CNV farms were associated with abundance patterns of specific pests and natural enemies, these management schemes were generally robust to variable pest control challenges on individual farms.

Conclusions

For any given combination of crop, location, labour and capital availability conditions there are potentially several optimum crop protection strategies. Different crop production or protection strategies include schedule-based prevention, integrated pest management, organic, traditional, biodynamic, biological or ecological practices. Alternative strategies may rely on fundamentally different conceptual approaches, yet also function as viable suites of best management practices for crop production. Andow and Hidaka (1989) demonstrated the idea of such 'syndromes of production' using Shizen and conventional rice farming management schemes, and show that qualitatively different sets of integrated practices can produce favourable outcomes in terms of yields and profit. We suggest here that for most conventional crop production systems in most locales, viable alternatives, including organic agricultural schemes, either already are in practice or are possible. To support and develop alternative crop protection schemes that are economically, socially and environmentally sustainable, alternative lines of research, price supports, agricultural policies, and land-use practices may need to be embraced. To optimise crop protection in organic agriculture, research should be geared to defining and accessing suites of crop production materials and practices that work in concert as a favourable production syndrome (*sensu* Andow and Hidaka 1989). We suggest four key research areas for crop protection improvement in organic agriculture.

Future research directions

Knowledge banks from natural systems studies and comparisons with agroecosystems

The application of ecological principles to pest regulation in agroecosystems is extremely important for advancing crop protection through ecosystem services. However, the staggering amount of diversity in habitats and life histories among pests and pathogens defies any strict adherence to generalities. Therefore, technological advances in data management and expert systems can now be used to synthesise detailed results from relevant ecological studies as a basis for making specific decisions in pest management. Further, the degree to which results from ecological studies in natural systems can be transferred to understanding plant–arthropod, disease–host, and predator–prey interactions in agroecosystems is, for the most part, speculative. Future comparative studies between natural and managed habitats are needed to test common assumptions (Barbosa 1998) and create a realistic set of goals and practices for organic growers.

Development of cultivars suited to organic farming conditions and needs

Breeding for resistant cultivars under organic management conditions should be a high priority. Herbivores that exploit cultivated varieties often encounter resources that differ in fundamental ways from the plants' wild relatives. Attributes that have arisen out of a selection process for enhanced productivity and palatability under conventional conditions tend to increase the crop's suitability as a host for phytophagous arthropods and pathogens. First, compared to their progenitors, crop plants can contain lower levels and simplified suites of antiherbivore defences (Kennedy and Barbour 1992), can possess a more uniform genetic composition, and may experience lower levels of plant stress. Second, the presentation of these plants to herbivores and pathogens differs from the conditions found in most of the communities of their wild relatives in its tendency for uniformity in species composition, age distribution of the population, and structural pattern. Each of these factors contributes to the need for research into optimised plant resistance in different management contexts and cropping systems.

Optimisation of production of healthy seed and vegetative propagating materials

Organic crop production can be very successful provided that healthy seed and vegetative propagating materials are used, since the options for intervention are limited once the crop is in the field. The best option would be to produce seeds and vegetative materials in pest and disease-free areas (i.e. in isolated regions with arid climates). However, organic agriculture may not be well established in such regions, and facilities for tissue culture and seed health testing may not be available, for example in northern Africa. A combination of biological, social and economic research would be needed to optimise the production in such regions in close collaboration with local farmers. Additional research would be desirable to develop and test plant extracts and microbial communities for biological control of seedling diseases, and to formulate these products so that they can be approved by organic certification agencies.

Assessment of the role of landscape factors for colonisation of pests, pathogens and natural enemies

Vegetation at the field margin or in surrounding areas serves as coloniser sources for mobile pests, vectors, and pathogens. The degree to which organic crop fields are colonised, exploited and damaged may depend upon the quality of these source pools. Vegetation management may reduce pest and pathogen levels directly or may serve to stabilise and enhance predators and parasitoids for biological control of crop pests. Rigorous analyses of landscape-scale phenomena, though recognised as critical for decades (e.g. a 'wide-area view' *sensu* Rabb 1978), are only recently becoming feasible with new geographical information systems capabilities (e.g. Marino and Landis 1996, Letourneau and Goldstein 2001, Thies *et al*. 2003) and metapopulation dynamics models.

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References

Abbasi, P.A., Al-Dahmani, J., Sahin, F., Hoitink, H.A.J. and Miller, S.A. 2002. Effect of compost amendments on disease severity and yield of tomato in conventional and organic production systems. *Plant Disease* 86: 156–161.

Agricultural Issues Center 1988. *Agricultural Chemicals in California Plant Production: Are There Alternatives*? University of California, Davis.

Agrios, G.N. 1997. *Plant Pathology*. Academic Press, San Diego.

Altieri, M.A. 1999. The ecological role of biodiversity in agroecosystems. *Agriculture, Ecosystems and Environment* 74: 19–31.

Altieri, M.A. 1986. The ecology of insect pest control in organic farming systems: toward a general theory. In: Vogtmann, H., Boehncke, E. and Fricke, I. (eds) *Importance of Biological Agriculture in a World of Diminishing Resources*: *Proceedings of the 5th IFOAM International Scientific Conference*. University of Kassel. pp. 405–420. International Federation of Organic Agriculture Movements, Tholey-Theley, Germany.

Alvarez, T., Frampton, G.K., Goulson, D. 2001. Epigeic collembola in winter wheat under organic, integrated and conventional farm management regimes. *Agriculture Ecosystems and Environment* 83: 95–110.

Andow, D.A. 1983. Effect of agricultural diversity on insect populations. In: Lockeretz, W. (ed.) *Environmentally Sound Agriculture : Selected Papers, 4th conference, International Federation of Organic Agriculture Movements, Cambridge, Massachusetts, 18–20August 1982*. Praeger, New York. pp. 91–115.

Andow, D.A. 1991. Vegetational diversity and arthropod population response. *Annual Review of Entomology* 36: 561–586.

Andow, D.A. and Hidaka, K. 1989. Experimental natural history of sustainable agriculture: syndromes of production. *Agriculture Ecosystems and Environment* 27: 471–475.

Asteraki, E.J., Hart, B.J., Ings, T.C. and Manley, W.J. 2004. Factors influencing the plant and invertebrate diversity of arable field margins. *Agriculture Ecosystems and Environment* 102: 219–231.

Aude, E., Tybirk, K., Michelsen, A., Ejrnaes, R., Hald, A.B. and Mark, S. 2004. Conservation value of the herbaceous vegetation in hedgerows – does organic farming make a difference? *Biological Conservation* 118: 467–478.

Barbosa, P. (ed.) 1998. *Conservation Biological Control*. Academic Press, San Diego.

Basedow, T. 1991. Population density and biomass of epigeal predatory arthropods natural enemies of insect pests in winter wheat fields of areas with extremely different intensity of agricultural production. *Zeitschrift Fuer Pflanzenkrankheiten und Pflanzenschutz* 98: 371–377.

Basedow, T. 1995. Insect pests, their antagonists and diversity of the arthropod fauna in fields of farms managed at different intensities over a long term – a comparative survey. *Mitteilungen der Deutschen Gesellschaft fur Allgemeine und Angewandte Entomologie* 10: 565–572.

Basedow, T. 1998. The species composition and frequency of spiders (Araneae) in fields of winter wheat grown under different conditions in Germany. *Journal of Applied Entomology* 122: 585–590.

Bergvinson, D.J., Arnason, J.T., Hamilton, R.I., Mihm, J.A., Jewell, D.C. 1994. Determining leaf toughness and its role in maize resistance to the European corn–borer (Lepidoptera, Pyralidae). *Journal of Economic Entomology* 87: 1743–1748.

Berkelmans, R., Ferris, H., Tenuta, M., and van Bruggen, A.H.C. 2003. Long-term effects of crop management on trophic levels of nematodes other than plant parasitic nematodes disappear after one year of uniform treatment. *Applied Soil Ecology* 23: 223–235.

Berlath, M., Backes, F., Krämer, J. 1998. Mould spectrum and mycotoxins (Deoxynivalenol and Ochratoxin A) in grain samples from ecological and integrated cultivated sites. *Agribiological Research* 51: 369–376.

Berry, N.A., Wratten, S.D., McErlich, A. and Frampton, C. 1996. Abundance and diversity of beneficial arthropods in conventional and organic carrot crops in New Zealand. *New Zealand Journal of Crop and Horticultural Science* 24: 307–313.

Birzele, B., Meier, A., Hindorf, H., Krämer, J., and Dehne, H.W. 2002. Epidemiology of Fusarium infection and deoxynivalenol content in winter wheat in the Rhineland, Germany. *European Journal of Plant Pathology* 108: 667–673.

Booij, C.J.H. and Noorlander, J. 1992. Farming systems and insect predators. *Agriculture Ecosystems and Environment* 40: 125–135.

Bukovinszky, T. 2004. *Tailoring Complexity: Multitrophic Interactions in Simple and Diversified Habitats*. PhD thesis, Wageningen University.

Bukovinszky, T., Trefas, H., van Lenteren, J.C., Vet, L.E.M. and Fremont, J. 2004. Plant competition in pest-suppressive intercropping systems complicates evaluation of herbivore responses. *Agriculture Ecosystems and Environment* 102: 185–196.

Bulluck, L.R. and Ristaino, J.B. 2002. Effect of synthetic and organic soil fertility amendments on southern blight, soil microbial communities, and yield of processing tomatoes. *Phytopathology* 92: 181–189.

Bulluck, L.R., Brosius, M., Evanylo, G.K. and Ristaino, J.B. 2002. Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties on organic and conventional farms. *Applied Soil Ecology* 19: 147–160.

Bulson, H.A.J., Snaydon, R.W. and Stopes, C.E. 1997. Effects of plant density on intercropped wheat and field beans in an organic farming system. *Journal of Agricultural Science* 128: 59–71.

Champeil, A., Fourbet, J.F, Dore, T. and Rossignol, L. 2004. Influence of cropping system on *Fusarium* head blight and mycotoxin levels in winter wheat. *Crop Protection* 23: 531–537.

Clark, M.S., Ferris, H., Klonsky, K., Lanini, W.T., Bruggen, A.H.C., and Zalom, F.G. 1998. Agronomic, economic, and environmental comparison of pest management in conventional and alternative tomato and corn systems in northern California. *Agriculture Ecosystems and Environment* 68: 51–71.

Corrales, N. and Campos, M. 2004. Populations, longevity, mortality and fecundity of *Chrysoperla carnea* (Neuroptera, Chrysopidae) from olive-orchards with different agriculture management systems. *Chemosphere* 57: 1613–1619.

Czerwiecki, L., Czajkowska, D. and Witkowska-Gwiazdowska, A. 2002. On ochratoxin A and fungal flora in Polish cereals from conventional and ecological farms. Part 2: Occurrence of ochratoxin A and fungi in cereals in 1998. *Food Additives and Contaminants* 19: 1051–1057.

Daamen, R.A., Wijnands, F.G. and van der Vliet, G. 1989. Epidemics of diseases and pests of winter wheat at different levels of agrochemical input. A study on the possibilities of designing an integrated cropping system. *Journal of Phytopathology* 125: 305–319.

Daugaard, H. 1999. Cultural methods for controlling *Botrytis cinerea* Pers. in strawberry. *Biological Agriculture and Horticulture* 16: 351–361.

Degen, T., Dillman, C., Marion-Poll, F., and Turlings, T.C.J. 2004. High genetic variability of herbivore-induced volatile emission within a broad range of maize inbred lines. *Plant Physiology* 135: 1928–1938.

Delate, K., Friedrich, H. and Lawson, V. 2003. Organic pepper production systems using compost and cover cops. *Biological Agriculture and Horticulture* 21: 131–150.

Deschenes, M., Belanger, L. and Giroux, J.-F. 2003. Use of farmland riparian strips by declining and crop damaging birds. *Agriculture, Ecosystems and Environment* 95: 567–577.

Drinkwater, L.E., Letourneau, D.K., Workneh, F., van Bruggen, A.H.C., and Shennan, C. 1995. Fundamental differences between conventional and organic tomato agroecosystems in California. *Ecological Applications* 5: 1098–1112.

Engelhard, A.W. (ed.) 1989. *Soilborne Plant Pathogens: Management of Diseases with Macro- and Microelements*. APS Press, St Paul.

Feber, R.E., Firbank, L.G., Johnson, P.J. and Macdonald, D.W. 1997. The effects of organic farming on pest and non-pest butterfly abundance. *Agriculture, Ecosystems and Environment* 64: 133–139.

Felix D'Mello. J.P., MacDonald, A.M.C., Postel, D., Dijksma, W.T.P., Dujardin, A. and Placinta, C.M. 1998. Pesticide use and mycotoxin production in *Fusarium* and *Aspergillus* phytopathogens. *European Journal of Plant Pathology* 104: 741–751.

Ferris, H., Venette, R.C. and Lau, S.S. 1996. Dynamics of nematode communities in tomatoes grown in conventional and organic farming systems, and their impact on soil fertility. *Applied Soil Ecology* 3: 161–175.

Finckh, M.R. 1997. The use of biodiversity to restrict plant diseases and some consequences for farmers and society. In: Jackson, L.E. (ed.) *Ecology in Agriculture*. Academic Press, San Diego. pp. 203–237.

Finckh, M.R., Gacek, E.S., Goyeau, H., Lannou, C., Merz, U., Mundt, C.C., Munk, L., Nadziak, J., Newton, A.C., de Vallavieille-Pope, C. and Wolfe, M.S. 2000. Cereal variety and species mixtures in practice, with emphasis on disease resistance. *Agronomie*. 20: 813–837.

Fravel. 1999. Hurdles and bottlenecks on the road to biocontrol of plant pathogens. *Australasian Plant Pathology* 28: 53–56.

Gliessman, S.R. 2001. Agroecosystem sustainability: developing practical strategies. *Advances in Agroecology*. CRC Press, Boca Raton.

Gliessman, S.R., Werner, M.R., Sweezy, S., Caswell, E., Cochran, J. and Rosado-May. F. 1996. Conversion to organic strawberry management changes ecological processes. *California Agriculture* 50: 24–31.

Guthman, J. 2000. Raising organic: an agroecological assessment of grower practices in California. *Agriculture and Human Values* 17: 257–266.

Haines, C.P. 2000. IPM for food storage in developing countries: 20th Century aspirations for the 21st century. *Crop Protection* 19: 825–830.

Hannukala, A.O. and Tapio, E. 1990. Conventional and organic cropping systems at Suitia V: Cereal diseases. *Journal of Agricultural Science Finland* 63: 339–347.

Hesler, L.S, Grigarich, A.A., Oraze, M.J., and Palrang, A.T. 1993. Arthropod fauna of conventional and organic rice fields in California. *Journal of Economic Entomology* 86: 149–158.

Hiddink, G.A., van Bruggen, A.H.C., Termorshuizen, A.J., Raaijmakers, J.M. and Semenov, A.V. (2005). Effect of organic management of soils on suppressiveness to *Gaeumannomyces graminis* var. *tritici* and its antagonist *Pseudomonas fluorescens*. *European Journal of Plant Pathology* 113: 417–435.

Higginbotham, S. 1996. The monitoring of disease levels in organic and conventionally managed wheat. *Aspects of Applied Biology* 47: 167–172.

Hofman, TW. 1988. *Effects of Granular Nematicides on the Infection of Potatoes by* Rhizoctonia solani. PhD thesis, Wageningen University.

Holland, J. and Fahrig, L. 2000. Effect of woody borders on insect density and diversity in crop fields: a landscape-scale analysis. *Agriculture, Ecosystems, and Environment* 78: 115.

Honek, A. 1997. The effect of plant cover and weather on the activity density of ground surface arthropods in a fallow field. *Entomological Research in Organic Agriculture* 15: 203–210.

Hossain, M.A., Choudhury, M.H.K., Hossain, M.F., and Alam, Q.K. 2002. Effects of ecological agriculture on soil properties and arthropod diversity in rice-based cropping systems in floodplain areas in Bangladesh. *Biological Agriculture and Horticulture* 20: 215–227.

Hummel, R.L., Walgenbach ,J.F., Hoyt, G.D. and Kennedy, G.G. 2002. Effects of production system on vegetable arthropods and their natural enemies. *Agriculture, Ecosystems and Environment* 93: 165–176.

Jafee, B.A., Ferris, H., Scow, K.M. 1998. Nematode-trapping fungi in organic and conventional cropping systems. *Phytopathology* 88: 344–350.

Jahn, M. 2003. On-farm and centralized approaches to breeding vegetables for organic farming systems. *Hortscience* 38: 866.

Jansson, R.K., and Lecrone, S.H. 1991. Effects of summer cover crop management on wireworm (Coleoptera, Elateridae) abundance and damage to potato. *Journal of Economic Entomology* 84: 581–586.

Johnson, M.W. and Tabashnik, B.E. 1999. Chapter 13: Enhanced biological control through pesticide selectivity. In: Bellows, T. and Fisher, T.W. (eds) *Handbook of Biological Control*. pp. 297–317. Academic Press, San Diego.

Knops, J.M.H., Tilman, D., Haddad, M.N., Naeen Shahid, Mitchell, C.E., Haarstad, J., Ritch, ME, Howe, K.M., Reich, P., Siemann, E., and Groth, J. 1999. Effect of plant species richness on invasion dynamics, disease outbreaks, insect abundance and diversity. *Ecology Letters* 2: 286–293

Lammerts van Bueren, E.T., Struik, P.C. and Jacobsen, E. 2003. Organic propagation of seed and planting material: an overview of problems and challenges for research. *Netherlands Journal of Agricultural Sciences* 51: 263–277.

Lampkin, N. 1999. *Organic Farming*. Farming Press, Ipswich.

Langer, V. 1995. Pests and disease in organically grown vegetables in Denmark: a survey of problems and use of control methods. *Biological Agriculture and Horticulture* 12: 151–171.

Lemmens, M., Haim, K., Lew, H. and Ruckenbauer, P. 2004. The effect of nitrogen fertilization on Fusarium head blight development and deoxynivalenol contamination in wheat. *Journal of Phytopathology* 152: 1–8.

Letourneau, D.K. 1994. Bean fly, management practices, and biological control in Malawian subsistence agriculture. *Agriculture, Ecosystems and Environment* 50: 103–111.

Letourneau, D.K. 1997. Plant–arthropod interactions in agroecosystems. In: Jackson L.E. (ed.) *Ecology and Agriculture*. Academic Press, New York. pp. 239–290.

Letourneau, D.K. and Altieri, M.A. 1999. Environmental management to enhance biological control in agroecosystems. In: Bellows, T. and Fisher, T.W. (eds) *Handbook of Biological Control*. Academic Press, San Diego.

Letourneau, D.K. and Goldstein, B. 2001. Pest damage and arthropod community structure in organic vs. conventional tomato production in California. *Journal of Applied Ecology* 38: 557–570.

Letourneau, D.K. and Msuku, M.A.B. 1992. Enhanced *Fusarium solani* f. sp. *phaseoli* infection by bean fly in Malawi. *Plant Disease* 76: 1253–1255.

Letourneau, D.K., Drinkwater, L.E. and Shennan, C. 1996. Effects of soil management on crop nitrogen and insect damage in organic vs. conventional tomato fields. *Agriculture, Ecosystems and Environment* 57: 179–187.

Litterick, A.M., Harrier, L., Wallace, P., Watson, C.A. and Wood, M. 2004. The role of uncomposted materials, composts, manures, and compost extracts in reducing pest and disease incidence and severity in sustainable temperate agricultural and horticultural crop production – a review. *Critical Reviews in Plant Sciences* 23: 453–479.

Lotter, D.W., Granett, J. and Omer, A.D. 1999. Differences in grape *Phylloxera*-related grapevine root damage in organically and conventionally managed vineyards in California. *Hortscience* 34: 1108–1111.

Mäder, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P. and Niggli, U. 2002. Soil fertility and biodiversity in organic farming. *Science* 296: 1694–1697.

Mahli, CS. 2000. Timings of operations to control damage by rose-ringed parakeets to maturing sunflower crops and their relationship with sowing times. *International Pest Control* 42(3): 86–88.

Manici, L.M., Ciavatta, C., Keldere, M. and Erschbaumer, G. 2003. Replant problems in South Tyrol: role of fungal pathogens and microbial population in conventional and organic apple orchards. *Plant and Soil* 256: 315–324.

Marino, P.C. and Landis, D.A. 1996. Effect of landscape structure on parasitoid diversity and parasitism in agroecosystems. *Ecological Applications* 6: 276–284.

Mazzola, M., Andrews, P.K., Reganold, J.P. and Levesque, C.A. 2002. Frequency, virulence, and metalaxyl sensitivity of *Pythium* spp. isolated from apple roots under conventional and organic production systems. *Plant Disease* 86: 669–675.

Moreby, S.J. and Sotherton, N.W. 1997. A comparison of some important chick-food insect groups found in organic and conventionally-grown winter wheat fields in southern England. *Biological Agriculture and Horticulture* 15: 51–60.

Moreby, S.J., Aebischer, N.J., Southway, S.E., and Sotherton, N.W. 1994. A comparison of the flora and arthropod fauna of organically and conventionally grown winter wheat in southern England. *Annals of Applied Biology* 12: 13–27.

Mukhopadhyay, A., Sherpa, P.W., and Pradhan, B. 2003. Diversity of ground arthropod community at organic and chemically intensive tea plantation of Darjeeling terai. *Journal of Environmental Biology* 24: 471–476.

Mundt, C.C. 2002. Use of multiline cultivars and cultivar mixtures for disease management. *Annual Review of Phytopathology* 40: 381–410.

Neher, D.A. and Olson, R.K. 1999. Nematode communities in soils of four farm cropping management systems. *Pedobiologia* 43: 430–438.

Oehl, F., Sieverding, E., Mäder, P., Dubois, D., Ineichen, K., Boller, T. and Wiemken, A. 2004. Impact of long-term conventional and organic farming on the diversity of arbuscular mycorrhizal fungi. *Oecologia* 138: 574–583.

Peachey, R.E., Moldenke, A., William, R.D., Berry, R., Ingham, E. and Groth, E. 2002. Effect of cover crops and tillage system on symphylan (Symphyla: *Scutigerella immaculata*, Newport) and *Pergamasus quisquiliarum* Canestrini (Acari : Mesostigmata) populations, and other soil organisms in agricultural soils. *Applied Soil Ecology* 21: 59–70.

Pearsall, I.A. and Walde, S.J. 1995. A comparison of epigaeic coleopteran assemblages in organic, conventional, and abandoned orchards in Nova-Scotia, Canada. *Canadian Entomologist* 127: 641–658.

Peterson, G., Allen, C.R. and Holling, C.S. 1998. Ecological resilience, biodiversity, and scale. *Ecosystems* 1: 6–18.

Pfiffner, L. and Niggli, U. 1996. Effects of bio-dynamic, organic and conventional farming on ground beetles (Col. Carabidae) and other epigaeic arthropods in winter wheat. *Biological Agriculture and Horticulture* 12: 353–364.

Phelan, P.L. 1997. Soil-management history and the role of plant mineral balance as a determinant of maize susceptibility to the European corn borer. *Biological Agriculture and Horticulture* 15: 25–34.

Phillips, S.W., Bale, J.S. and Tatchell, G.M. 1999. Escaping an ecological dead-end: asexual overwintering and morph determination in the lettuce root aphid *Pemphigus bursarius* L. *Ecological Entomology* 24: 336–344.

Pickett, C.H. and Bugg, R. (eds). 1998. *Enhancing Biological Control: Habitat Management to Promote Natural Enemies of Agricultural Pests*. University of California Press, Berkeley.

Pimentel, D., Krummel, J., Gallahan, D., Hough, J., Merrill, A., Schreiner, I., Vittum, P., Koziol, F., Back, E., Yen, D., and Fiance, S. 1981. A cost-benefit analysis of pesticide use in U.S. food production. I: Pimentel, D. (ed.) *CRC Handbook of Pest Management in Agriculture, Vol. II*. CRC Press, Boca Raton.

Pimentel, D., McLaughlin, L., Zepp, A. and Lakitan, B. 1991. Environmental and economic effects of reducing pesticide use. A substantial reduction in pesticides might increase food costs only slightly. *BioScience* 41: 402–409.

Piorr, H.P. and Hindorf, H. 1986. The implication of plant diseases and pests during the conversion from conventional to biological agriculture. In: Vogtmann, H., Boehnke, E. and Fricke, I. (eds) *The Importance of Biological Agriculture in a World of Diminishing Resources*. Verlagsgruppe, Witzenhausen. pp. 421–435.

Poudel, D.D., Ferris, H., Klonsky, K., Horwath, W.R., Scow, K.M., van Bruggen, A.H.C., Lanini, W.T., Mitchell, J.P. and Temple, S.R. 2001. The sustainable agriculture farming system project in California's Sacramento Valley. *Outlook on Agriculture* 30: 109–116.

Rabb, R.L. 1978. A sharp focus on insect populations and pest management from a wide-area view. *Bulletin of the Entomological Society of America* 24: 55–61.

Rabbinge, R. and Zadoks, J.C. 1989. Disease and pest control. In: Zadoks, J.C. (ed.) *Development of Farming Systems. Evaluation of the Five-Year Period 1980–1984*. Pudoc, Wageningen. pp. 32–39.

Reddersen, J. 1997. The arthropod fauna of organic versus conventional cereal fields in Denmark. *Biological Agriculture and Horticulture* 15: 61–71.

Rhainds, M., Kovach, J. and English-Loeb, G. 2002. Impact of strawberry cultivar and incidence of pests on yield and profitability of strawberries under conventional and organic management systems. *Biological Agriculture and Horticulture* 19: 333–353.

Riggs, R.D. 1959. Studies on resistance in tomato to root-knot nematodes. *Dissertation Abstracts* 19: 2710.

Rosado-May, F.J., Werner, M.R., Gliessman, S.R. and Webb, R. 1994. Incidence of strawberry root fungi in conventional and organic production systems. *Applied Soil Ecology* 1: 261–267.

Rosenthal, G.A. and Janzen, D.H. (eds) 1979. *Herbivores: Their Interaction with Secondary Plant Metabolites*. Academic Press, New York.

Ryan M. 1999. Is an enhanced soil biological community, relative to conventional neighbours, a consistent feature of alternative (organic and biodynamic) agricultural systems? *Biological Agriculture and Horticulture* 17: 131–144.

Schollenberger, M., Suchy, S., Jara, H.T., Drochner, W. and Mueller, H.M. 1999. A survey of Fusarium toxins in cereal-based foods marketed in an area of southwest Germany. *Mycopathologia* 147: 49–57.

Schollenberger, M., Jara, H.T., Suchy, S., Drochner, W. and Mueller, H.M. 2002. Fusarium toxins in wheat flour collected in an area in southwest Germany. *International Journal of Food Microbiology* 72: 85–89.

Scriber, J.M. 1984 Nitrogen nutrition of plants and insect invasion. In: Hauck, R.D. (ed.) *Nitrogen in Crop Production*. American Society of Agronomy, Madison. pp. 441–460.

Shah, P.A., Brooks, D.R., Ashby, J.E., Perry, J.N. and Wolwod, I.P. 2003. Diversity and abundance of the coleopteran fauna from organic and conventional management systems in southern England. *Agricultural and Forest Entomology* 5: 51–60.

Spruijt-Verkerke, J., Schoorlemmer, H., van Woerden, S., Peppelman, G., de Visser, M. and Vermeij, I. 2004. *Duurzaamheid van de Biologische Landbouw. Prestaties op Milieu, Dierenwelzijn en Arbeidsomstandigheden. [Sustainability of Organic Agriculture. Accomplishments in Environment, Animal Welfare, and Labour Conditions].* Praktijkonderzoek Plant and Omgeving. PPO 328, Wageningen UR.

Sullivan, T.P. and Sullivan, D.S. 2004. Influence of a granivorous diversionary food on population dynamics of montane voles (*Microtus montanus*), deer mice (*Peromyscus maniculatus*), and western harvest mice (*Reithrodontomys megalotis*). *Crop Protection* 23(3): 191–200.

Tamis, W.L.M. and van den Brink, W.J. 1998. *Inventarisatie van ziekten en plagen in wintertarwe in gangbare, geïntegreerde en ecologische teeltsystemen in Nederland in de periode 1993–1997.* IPO–DLO Rapport nr. 98–01. Wageningen.

Tamis, W.L.M., and van den Brink, W.J. 1999. Conventional, integrated and organic winter wheat production in the Netherlands in the period 1993–1997. *Agriculture Ecosystems and Environment* 76: 47–59.

Tamm, L., Schueler, C., Möller, K., and Finckh, M.R. 1999. The current situation of organic potato production in Europe. In: *Global Initiative on Late blight: A Threat to Global Food Security.* Centro Internacional de la Papa, Lima. p. 26.

Teviotdale, B.L. and Hendricks, L. 1994. Survey of mycoflora inhabiting almond fruit and leaves in conventionally and organically farmed orchards. *Acta Horticulturae* 373: 177–183.

Thies, C., I. Steffan-Dewenter and T. Tscharntke. 2003. Effects of landscape context on herbivory and parasitism at different spatial scales. *Oikos* 101: 18–25.

Thresh, J.M. 1982. Cropping practices and virus spread. *Annual Review of Phytopathology* 20: 193–218.

Trewavas, A. 2004. A critical assessment of organic farming-and-food assertions with particular respect to the UK and the potential environmental benefits of no-till agriculture. *Crop Protection* 23: 757–781.

van Bruggen, A.H.C. 1995. Plant-disease severity in high-input compared to reduced-input and organic farming systems. *Plant Disease* 79: 976–984.

van Bruggen, A.H.C. and Semenov, A.M. 2000. In search of biological indicators for soil health and disease suppression. *Applied Soil Ecology* 15: 13–24.

van Bruggen, A.H.C. and Termorshuizen, A.J. 2003. Integrated approaches to root disease management in organic farming systems. *Australasian Plant Pathology* 32: 141–156.

Van Emden, H.F. 1966. Studies on the relations of insect and host plant. III. A comparison of the reproduction of *Brevicoryine brassicae* (L.) and *Myzus persicae* (Sulz.) (Hem: Aphididae) on Brussels sprout plants supplied with different rates of nitrogen and potassium. *Entomologia Experimentalis et Applicata* 9: 444–460.

Weibull, A.C., Ostman, O. and Granqvist, A. 2003. Species richness in agroecosystems: the effect of landscape, habitat and farm management. *Biodiversity and Conservation* 12: 1335–1355.

Wenneker M., Verdel, M.S.W., Groeneveld, R.M.W., Kempenaar, C., van Beuningen, A.R. and Janse, J.D. 1999. *Ralstonia* (*Pseudomonas*) *solanacearum* race 3 (biovar 2) in surface water and natural weed hosts: first report on stinging nettle (*Urtica dioica*). *European Journal of Plant Pathology* 105: 307–315.

Whitham, T.G. and Slobodchikoff, C.N. 1981. Evolution by individuals: plant herbivore interactions and mosaics of genetic variability – the adaptive significance of somatic mutations in plants. *Oecologia* 49: 287–292.

Wickramasinghe, L.P., Harris, S., Jones, G., Vaughan, N. 2003. Bat activity and species richness on organic and conventional farms: impact of agricultural intensification. *Journal of Applied Ecology* 40 (6), 984–993.

Workneh, F. and van Bruggen, A.H.C. 1994a. Suppression of corky root of tomatoes in soils from organic farms associated with soil microbial activity and nitrogen status of soil and tomato tissue. *Phytopathology* 84: 688–694.

Workneh, F. and van Bruggen, A.H.C. 1994b. Microbial density, composition, and diversity in organically and conventionally managed rhizosphere soil in relation to suppression of corky root of tomatoes. *Applied Soil Ecology* 1: 219–230.

Workneh, F., van Bruggen, A.H.C., Drinkwater, L.E., and Shennan, C. 1993. Variables associated with corky root and Phytophthora root rot of tomatoes in organic and conventional farms. *Phytopathology* 83: 581–589.

Wyss, E., Lammerts van Bueren, E., Hulscher, M. and Haring, M. 2001. *Plant Breeding Techniques. An Evaluation of Organic Plant Breeding.* Forschungsinstitut für biologischen Landbau, Frick.

Vaarst, M., Roderick, S., Lund, V., Lockeretz, W. and Hovi, M. 2003. Organic principles and values: the framework for organic animal husbandry. In: Vaarst, M., Roderick, S., Lund, V. and Lockeretz, W. (eds) *Animal Health and Welfare in Organic Agriculture*. CABI Publishing, Wallingford. pp. 1–12.

Vossen, P.M., Jolly, D., Meyer, R., Varela, L. and Blodgett, S. 1994. Comparing organic and conventional apple production in Sonoma County. *California Agriculture* 48: 5.

Zwankhuizen, M.J., Govers, F. and Zadoks, J.C. 1998. Development of potato late blight epidemics: disease foci, disease gradients, and infection sources. *Phytopathology* 88: 754–763.

Chapter 5

Organic plant breeding and seed production: ecological and ethical aspects

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Introduction

Like all farmers, organic farmers look for the best varieties for their farm conditions. The pool of varieties to choose from consists, in many cases, of 'conventional' varieties, bred for conventional agricultural systems in which high levels of artificial fertilisers and agrochemicals are widely used to control or overrule external factors. For such farming systems, conventional plant breeding can aim at optimising yield at high input. As organic farmers refrain from such chemical inputs, it seems logical that requirements for varieties suitable for organic farming systems should be based on optimising yield at lower input and stabilising yields under less controllable conditions. Most variety trials, though, show that the organic sector can profit from the progress in plant breeding and that modern varieties also fulfil some of the important needs of organic farmers (Stöppler *et al.* 1989). Not only has the yield potential of varieties increased but also the level of disease resistances has improved in some crops, such as tomato (Williams and St Clair 1993).

That many organic farmers in developed countries use modern varieties does not imply that those varieties are the best ones for organic agriculture. Given that attention is often focused on developing other agronomic areas of their farming systems, organic farmers have long accepted their dependence on conventional breeding. However, now more attention is being paid to the question of how to develop better-adapted varieties for organic farming systems. This question is even more urgent since genetic engineering has become important in conventional plant breeding and being dependent on conventional breeding would therefore no longer be an option. The organic sector realised that it is not only concerned about the variety traits as such but also about how varieties are bred and propagated, and thus whether breeding and propagation methods comply with both the ecological and ethical principles in organic agriculture (Bullard *et al.* 1994).

Such principles applied in the organic sector can be reflected in the concept of 'naturalness', which encompasses three approaches:

1 the non-chemical approach;
2 the agroecological approach; and
3 the ethical approach in which the integrity of life is taken into account (Verhoog *et al.* 2003).

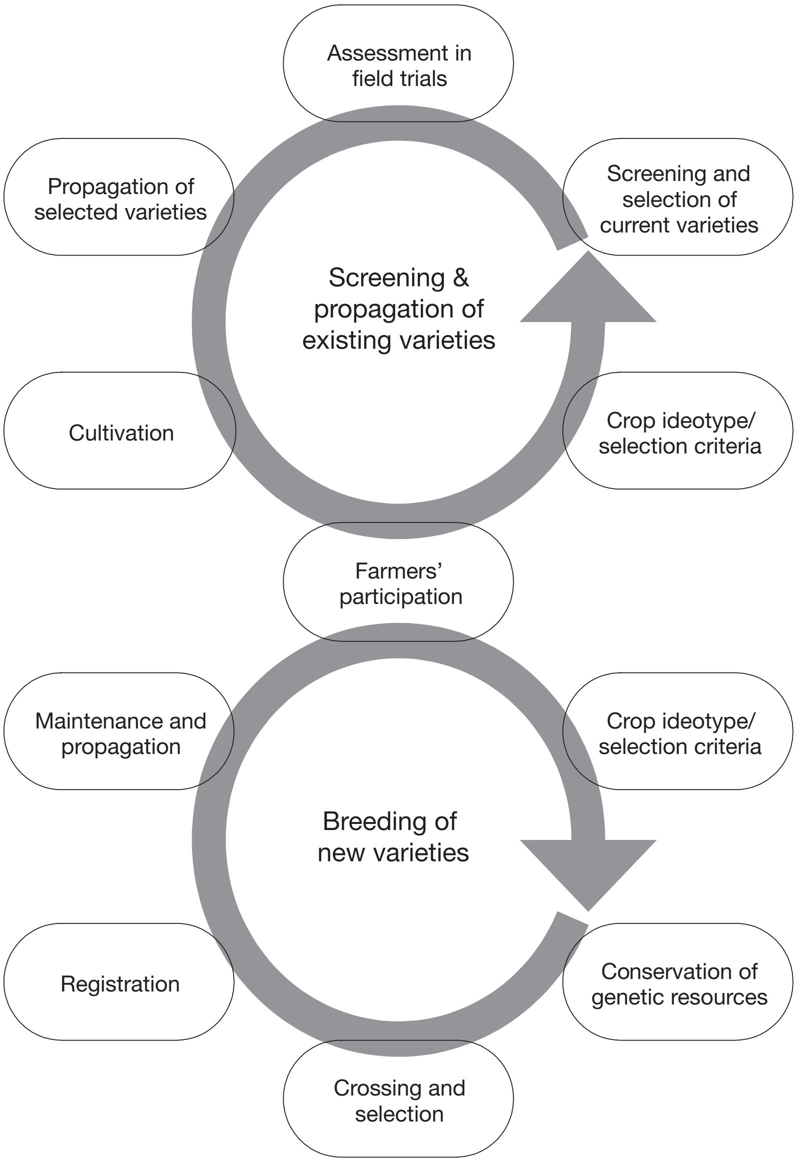

Figure 5.1 A flow chart of organic plant breeding and propagation.

To arrive at varieties and seeds produced in accordance with the needs and principles of organic agriculture the whole plant breeding and propagation chain will need additional research efforts and practical steps (Figure 5.1). It involves both defining crop ideotypes, and screening and selection of existing varieties for propagation, and *in situ* conservation of genetic resources, developing crop ideotypes and selection criteria for breeding programs, including registration and maintenance activities.

As the development of each new variety takes at least ten years and a lot of resources, the development towards varieties adapted to organic farming conditions will have to be taken in steps (Table 5.1).

Table 5.1 A time schedule for steps and results towards organic varieties and seed production

Time	Approach	Activity	Product
Current (2005) ↓	(Primarily) non-chemical approach	Defining desired traits Variety screening Refrain from postharvest, chemical seed treatments No use of transgenic engineering	Untreated seeds from conventional varieties
Short-term (2005–10) ↓	Non-chemical approach Including an agroecological approach	Organic propagation Organic seed treatments	Conventional varieties, but organically propagated (organic seeds)
Mid-term (2010–20) ↓	Non-chemical approach Agroecological approach	Organic VCU-testing protocols Conventional plant breeding programs including some low-input selection criteria	Low-input varieties Organically propagated (organic seeds)
Long-term (beyond 2020)	Non-chemical approach Agroecological approach Including the concept of integrity of life	Breeding/selection and maintenance under organic farm conditions With techniques that allow crossing, pollination, fertilisation and seed formation on the whole plant itself	Organic varieties Organic seeds

The first step in the short run is to define desired characteristics and select the best performing varieties from the existing assortment. The second step in closing the organic production chain is stimulating organic seed production of the above selected varieties. This is forced in Europe by the EU regulation 2092/91 that allows no more derogation (i.e. formal substitution of an organic input with a conventional input where no organic input can be found) for the use of conventionally propagated seed from 2004 onwards. This counts for those crops with already sufficient number of varieties appropriate for organic farming. Similar regulations have been enforced in the United States of America (USA) as part of the National Organic Program (NOP) (Sundrom 2004). Another important step is to influence the national procedures and protocols for testing of varieties for value for cultivation and use (VCU) and the release of new varieties, which is important to enlarge the chance of varieties entering the market with traits that are important for the organic sector. The step for the long run is developing breeding programs for the improvement of varieties adapted to the requirements of the organic food production.

For rapid and balanced progress in all these steps it is important to involve all stakeholders (farmers, traders, breeders, policy makers) in a participatory way in (research) projects to develop appropriate concepts and strategies and to solve practical obstacles (Lammerts van Bueren *et al*. 2003a; Peerenboom 2004).

In this chapter we specify the need for better adapted varieties, and describe possible ecological and ethical approaches to develop such varieties, and the attempts made to develop organic propagation of varieties to close the chain and refrain from conventionally produced inputs.

Variety characteristics

Variety choice in organic farming is an essential factor of successful production. But there is a significant lack of information on the performance of varieties under organic conditions. As conventional plant breeding aims at optimising yields under high inputs, the conventional variety testing selects for high performance under high input conditions. As the diversity of organic farming systems and conditions is large and results in a larger genotype–environment–management (G × E × M) interaction than in conventional agriculture, the organic farmer is more interested in varieties that have the ability to adapt to variable conditions and perform well with stable yields in different years at the specific site. In many countries there are variety trials under organic conditions but not for every crop and every year. Some are conducted by farmer groups, others by research stations or by commercial seed companies.

Yield stability and plant health

Long-term trials show that yields fluctuate much more in organic agriculture than in conventional agriculture. This is reflected by a larger coefficient of variation (Lammerts van Bueren *et al*. 2002, EFRC 2004). For some crops this year-to-year variation has become one of the most important factors that limits the growth of the organic market share (Spiertz 1989, Raupp 1996, Tamm 2000, Mäder *et al*. 2002). To reduce risks and increase yields the organic farmer first of all aims at system stability. That can be done through improving agronomic strategies and selecting appropriate varieties. For many crops one of the limiting factors influencing yield stability is the suitability of the available varieties. Organic farmers would rather have a variety with a reasonable yield and good stress tolerance than a variety that promises higher yield but largely loses that yield increase because of, for instance, disease susceptibility. Reliable varieties are those that can cope with unfavourable weather and soil conditions (e.g. fluctuating mineralisation rate of nutrients, assessed over several years). Farmers look for varieties that are, in general, more flexible and robust to support the self-regulating capacity of the organic farming system.

Conventional breeders often think that organic farmers require an absolute disease resistance, but in many cases tolerance or partial resistance can be sufficient. Organic farmers are used to searching for ways to reduce risks by an array of solutions at different levels (farm, crop, variety) and also adopt such a strategy in their search for appropriate combinations of supporting variety characteristics. There are different variety characteristics that support yield and yield stability through optimal plant health (Table 5.2). Plant health can be defined as a result of the following components:

1 escape – the crop is not exposed to a certain pest or disease;
2 resistance – the crop is exposed to the pest or disease but is not affected;
3 tolerance – the crop is affected by the pest or disease, but with a limited effect on the yield; and
4 ability to recover – the affected crop is able to recover to a certain extent.

Product quality

In the organic sector, the non-chemical approach also has effects on traits concerning product quality, such as long-term storability without chemical sprouting inhibitors for onions

Table 5.2 Variety characteristics supporting plant health in organic crop production

Mechanism	Variety characteristics
Escape	Shorter crop growth period and/or early ripening to be able to avoid the critical infestation period, or to have enough yield before the infestation becomes too severe (potato/late blight; onion/downy mildew; carrot/carrot fly)
Resistance	One or more monofactorial and multifactorial, durable resistance traits against pest and disease affecting yield and/or quality (scab/apple, late blight/potato, lettuce/downy mildew, yellow and brown leaf rust/wheat); weed competition by an allelochemical ability
Tolerance	Morphological or physiological traits to support reducing the risk of a rapid expansion of the infestation, such as for cereals: long stem, ear high above flag leaf, ear not too compact; leaf erectness/onion; hairy and tougher leaves against aphids/potato; wax layer on leaves against fungi/onion/cabbage. Stress tolerance in general by good adaptation to low(er)-input and organic inputs, ability to cope with fluctuating N-dynamics, efficient capturing of water and nutrients, deep and intensive root architecture; ability to interact with beneficial soil microorganisms, like mycorrhizae and atmospheric N-fixing bacteria; efficient nutrient uptake and high nutrient use efficiency. Plant architecture for early soil cover and more light-competition. Good combining ability in variety and species mixtures
Recovering ability	Good ability to recover from mechanical harrowing/cereals; high seedling vigour, fast and high germination percentage; deep and intensive root architecture

(Lammerts van Bueren *et al.* 2004b) and potato. In the case of fruit, a skin with a sufficiently thick natural wax layer, instead of a skin coated with synthetics, can positively influence longer storability. Organic bakeries try to avoid synthetic additives in the bread-baking process, but then require varieties with high baking quality and still sufficient yield under lower input conditions (Kunz *et al.* 1995; Kunz 2000; ITAB 2001; Welsh *et al.* 2001). Another aspect of quality is taste. Sensory qualities, such as taste, are not only a result of environmental and management factors but also of genetic influences. Although sensory quality has been added to organic breeding programs of carrot (Hagel *et al.* 2000), genetic variation for quality traits has not yet been fully explored.

Crop ideotypes

Priorities for required traits differ for each crop and market sector. To improve the communication between farmers, traders and breeders, crop ideotypes should be elaborated and designed for each crop. In the short run such crop ideotypes can contribute to a more adequate selection of appropriate varieties among the existing assortment of conventional varieties. But they are also necessary to achieve selection criteria for new varieties from breeding programs specifically focused on low-input and organic agriculture (Osman and Lammerts van Bueren 2002). Organic crop ideotypes have many selection criteria in common with conventional required traits, such as disease resistance and high yielding ability. The difference is that varieties for organic farming have to be able to perform well under low-input conditions. Another difference is additional supporting characteristics for plant health and yield potential, such as long stems, the ears being high above the flag leaf, and the ears not too compact. But also a characteristic such as a long stay green index for the top leaves in wheat is very important to enhance photosynthesis during the final phase of grain filling (Lammerts van Bueren *et al.* 2002).

It is important that the crop ideotypes have been designed with participation of farmers to include all practical experience as much as possible.

Variety testing

In many countries, especially in Europe, trading of seeds of varieties of arable crops is regulated, which means that varieties should be registered on a national variety list, a European list, or a list of another country. To become listed, the variety should be tested using the so-called VCU protocol by a designated institution and shown to outperform existing varieties. Such a conventional protocol is designed for testing varieties under conventional farming conditions and could, therefore, impede the introduction of new varieties with specific low-input traits that are not included in such a protocol. Another critical aspect is that some traits required for organic farming systems are not expressed under conventional conditions, such as nutrient efficient use of organic fertilisers.

Research organisations in some countries, for instance Austria, Germany, Switzerland and the Netherlands, have recently been successful in influencing the protocol for testing cereal varieties for the organic sector by including traits important for evaluation for organic farming systems and criteria to select research sites (Bonthuis *et al.* 2004; SUSVAR 2004). Official authorities have adopted such a protocol, and they are engaged in a process to allow VCU testing for cereal varieties under organic conditions. As most of this VCU testing is being financed as a research project that aims to compare the results with those gained under conventional testing, the future of this testing is uncertain.

Seed production

Organic seed production is still largely a missing link in the organic food production chain. Establishing organic seed production is also part of the process of developing new selection criteria for new varieties, from plant breeding, via maintenance to release and propagation of varieties. Although there have been many small-scale farmer initiatives to propagate varieties organically, large-scale use and production of organic seed production is still in its infancy. Some commercial companies have entered this market, but still not all existing or desired varieties are or can be propagated organically for technical or economic reasons (Van der Zeijden 2003). The two questions associated with organic seed production are:

1 which varieties should be propagated; and
2 how should it be done?

The first question is largely answered in the former paragraph, the second one will be addressed by discussing diversity, technical aspects and seed quality standards.

Diversity of varieties

In Europe and the USA, regulations no longer allow derogation for the use of conventionally propagated seeds of crops for which a sufficient assortment of organically propagated varieties and seed is already available. As this seed assortment usually consists of a minimum number of varieties, it has immediate consequences for the diversity of varieties that can be used in the organic sector and creates tension between short and long-term goals in the organic sector. There is the need not only to close the organic food supply chain as soon as possible to increase accountability for consumers, but also to have a diversity of varieties to meet the requirements of different market sectors and farming conditions.

There are roughly two groups of farmers involved in this difficult area. The first is those small-scale farmers who focus on the local market with the use of local and old varieties, the so-called conservation or heritage varieties. Often, such farmers care for a community-based and participatory seed production and exchange system to conserve the local varieties or maintain old varieties that are suitable for low-input conditions. These farmers are threatened by restrictions from the new regulations because many of those conservation or local varieties are not officially registered and/or not propagated organically. When they want to save their own seeds from modern varieties they have to deal with restrictive regulations on farmers' rights for saving their own seed.

The second group is large-scale farmers who produce for supermarkets and have to meet specific quality and uniformity requirements. These farmers depend largely on modern, hybrid varieties of commercial seed companies and on the breeding policy of such companies. For economic reasons, not all companies are willing to enter the relatively small, organic market and produce all the desired varieties organically. Those who do take part in organic seed production produce only a limited assortment, which constrains the choice compared with the larger assortment of conventionally propagated varieties. During the first World Conference on Organic Seed, held in Rome 2004 (IFOAM 2004), it was recognised that there are large differences between countries with and without a large critical mass of organic products and organic seeds. It can, for instance, restrict seed export from developing countries, where the commercial viability of organic seed is lacking and seed certification is not existent, to countries in Europe with strict regulations on the use of organically propagated seeds. A careful transitional period for shifting from conventional to organic seed is necessary.

Technical aspects

As organic farming systems refrain from the use of chemical protectants, it is even more important that seed and planting material is of high quality as these form the basis of crop production. The development of high quality propagating material requires the development of specific expertise on aspects of seed production including technical knowledge, choice of location and varieties (Lammerts van Bueren *et al.* 2003a).

The main problems in organic seed production are: nutrient management, disease and pest management, and weed control. Among the seedborne diseases in particular require special attention. To reduce the risk of disease infestation, optimal climatic conditions and thus the location for seed production can be important (Dornbusch *et al.* 1992; Velema 2004). In some cases seed production should be located in warmer and drier climates, away from the areas of origin and destination.

However, optimising organic seed production not only requires adapting cultural practices as mentioned above, but also that specific attention needs to be paid for variety traits during seed production. This applies especially to biennial vegetable crops, which can build up disease pressure in the first year and then suffer from a continued increase of disease pressure during seed formation in the following year. Another aspect that influences the success of organic seed production is that some parental lines of hybrids have reduced growth vigour and, therefore, are susceptible to biotic stresses including diseases. This implies that growth vigour as a variety characteristic is even more important in organic seed production than in conventional seed production.

Seed quality standards

Organic seed production without chemical inputs is a challenge for seed producers. The usual criteria for conventional seed quality also apply to organic seed: physical and genetic purity, absence of weed seeds, and a minimal requirement for germination. In some cases it is not always possible to produce seeds without a certain degree of contamination with diseases. Several methods can be applied to improve the seed quality. One method is grading and separating infected seeds from healthy seeds by selecting based on seed weight or size, as known in the case of *Fusarium* on cereal seeds. For some seedborne diseases additional postharvest, non-chemical treatments are needed, such as hot water or hot air treatments (Forsberg *et al*. 2000). However, more research is needed to optimise such methods to reduce the risk of damaging the seed (Jahn *et al*. 2004). Next to these physical treatments, disinfecting coatings with natural compounds are being developed, such as organic acids (mustard powder) or essential oils (thyme oil) (Groot *et al*. 2004). In seed potato there are positive results with treatments against *Rhizoctonia solani* with the antagonist *Verticillium biguttatum* (Hospers 1996).

For some crops there is no problem in meeting the quality standards as required for conventional seeds, but in some cases the thresholds for seedborne diseases are adjusted (Nielsen 2003; Lammerts van Bueren *et al*. 2003a; Girsch and Weinhappel 2004). In some countries the recommended tolerances or thresholds for some diseases are lowered. In Austria, for instance, the threshold for *Fusarium nivale* has been adjusted from 20% in conventional agriculture to 10% for the organic sector. In the Netherlands, the level of permitted contamination in organic seed potato has been lowered from 25% (conventional) to 10%. A lower threshold is also set in other diseases, for example, in Austria, 10% is permitted for *Septoria nodorum* in cereals, compared with 20% previously.

Plant breeding

Genetic diversity

Modern varieties have been developed with the aim of combining high productivity and uniform product quality under high input conditions. The situation concerning the G × E × M interaction is different for organic farming systems and thus, the goal for breeding programs. First, under low-input conditions farmers have to cope with more biotic and abiotic stresses and larger environmental variation within and between farms, so the E is high. Second, an organic farmer has fewer means to overrule that variation, so the M is low. This has consequences for the genetic input (G) and the demands on varieties are therefore higher (see *Yield stability and plant health)*. Organic farmers search for new varieties that possess a combination of required characteristics to increase yield stability under low-input, organic conditions. The question is how breeding can contribute to adapting crops and varieties to the organic, lower-input environment by improving the inherent buffering capacity of the farm system, and thereby, yield stability.

Modern varieties, such as those available for wheat, commonly lack the ability to adapt to different and changing environments, including drier regions with less fertile soils such as southern Australia (Kitchen *et al*. 2003). The tendency in conventional breeding is to select for single genotypes that have general adaptation to a large area where the variation in environments largely can be overruled by high inputs. Such varieties are ‘generalists’ and are not necessarily superior for nor adapted to a specific environment. As organic farming systems have fewer means to overrule agrodiversity, the variation in environmental conditions is larger, and therefore the need for a larger variation of so-called specialist varieties exists. But developing specialist varieties is difficult to achieve economically. Second, organic varieties need a certain degree of buffering capacity, which means that the conventional pedigree line breeding may have its limits on the performance of crops, such as wheat, in organic agriculture. Next to that problem, the current new varieties are mostly derived from a limited number of parental lines and are thus genetically closely related to each other.

The genetic base for an organic breeding program should be broadened and newly established. This aspect of broadening the base is even more important when searching for adaptation to organic farming. A broader genetic base can be achieved by creating composite cross populations followed by selection under organic farming conditions. In composite crosses many selected varieties are intercrossed and all the hybrids are bulked together for propagation. Those selected crossing parents can consist of not only modern high-yielding varieties, but also varieties bred before 1960 (before the period of high inputs) that are capable of more efficient nutrient uptake under low-input conditions, and from old landraces as a source for adaptability. This approach can form the base for further selection of individual, superior genotypes and lines as potentially new and better adapted varieties. We can also expect to select individual lines with a good combining ability for variety mixtures.

Variety mixtures formed by three or four existing varieties or extracted from composite cross populations are a simple and effective way of increasing the genetic diversity within a crop and improving yield stability (Finckh *et al.* 2000; Welsh and Wolfe 2003; Wolfe 2003). Mixtures can overcome several agronomic problems, through combining, for instance, high yielding types and types with a good baking quality and weed suppression in wheat. Research by conventional scientists indicates that there are areas of common interest to both organic and conventional plant breeders, for example, crop traits related to competitiveness against weeds (Lemerle *et al.* 1996) and soil-borne disease prevention (Smith *et al.* 2004).

However, any breeding strategy of restoring and enlarging functional genetic diversity requires reconsideration and adaptation of the legal and administrative frameworks. The regulations for registration are still based on the pure line practice. However, the market must be prepared to accept heterogeneous crops and products.

In situ and on-farm conservation of genetic resources

In order to maintain greater genetic diversity *in situ* and a wide gene pool to improve genetic resources for the organic sector, seeds from the formal (institutionalised or commercial) and informal (farmer-based) seed systems should be accessible to local and national breeding programs. There is a pronounced need to identify appropriate genetic resources either for direct use or as potential parental lines in breeding programs (Lammerts van Bueren *et al.* 2004a). There are well-organised initiatives dealing with *in situ* conservation of genetic resources in connection with organic agriculture, for instance ProSpecieRara in Switzerland (www.psrara.org), Arche Noah in Austria (www.arche-noah.at), the Seed Savers Exchange in the USA (www.seedsavers.org) or the Seed Savers' Network in Australia (www.seedsavers.net). The advantage of *in situ* conservation of genetic resources is that the accessions can coevolve and adapt to organic farm conditions.

Evaluating and exploiting gene bank material can be of use because required characteristics might have disappeared by selection under modern, high input conditions, such as low-input tolerance and deep or intensive root architecture (Foulkes *et al.* 1998; De Melo 2003). This is a relatively low cost method to develop valuable accessions.

Participatory selection

As the formal seed sector cannot start breeding programs for limited acreage of organic agriculture easily, alternative options should be developed to enhance varietal diversity. Decentralised and farmers' participatory approaches are known in developing countries and can offer an opportunity to combine knowledge and expertise of the organic farmers and that of formal breeders. Farmers can select in existing open-pollinating varieties or take part in the selection process of new crossings or developing base populations (see *Genetic diversity*).

There are different approaches to involving farmers in the breeding process (Ceccarelli 2000; Morris and Bellon 2004). In the traditional farmers' breeding model, farmers conduct the whole process of:

1 selection of source germplasm;
2 trait identification (prebreeding);

3 cultivar development; and
4 varietal evaluation.

In a complete participatory breeding model farmers are involved in all four activities in co-operation with breeders with a commercial or institutional background. On the other side there is the scientific breeding model completely conducted by the formal breeders. Morris and Bellon (2004) described other two approaches: the efficient participatory breeding model, in which formal breeders involve farmers in the phase of selecting source germplasm and in the end phase of evaluating potential varieties; and the participatory varietal selection model, in which farmers deal only with varietal evaluation. In the Netherlands, there is a long tradition of cooperation between the formal potato breeding sector and farmer breeders. Farmer breeders with their daily practical experience and developed intuition (farmer's eye) are involved in selecting the germplasm for new combinations together with the formal breeders. The formal breeder conducts the complex crossings between wild relatives and modern varieties, and offers the interested farmer breeders the seedlings for further selection during three years. The most promising phenotypes are delivered to the formal breeder or breeding company which will conduct further testing to see if it can end up in a variety (Van der Zaag 1999). Also organic farmers are involved in this participatory potato breeding system.

Benefits derived from new varieties bred by farmers require a legal system of common ownership that allows equitable access and benefits sharing. In many countries there are examples of networks of organic farmers and breeders that provide such a system (Henatsch 2002; Rios Labrada *et al*. 2002; Ramos Garcia *et al*. 2004).

Genetic modification, *in vitro* techniques and ethics

In ethical discussions about the application of modern biotechnology techniques, it is genetic engineering that attracts the most attention. A distinction is made between extrinsic arguments, dealing with the consequences of making genetically modified organisms (GMOs), and intrinsic arguments about the technology itself. There is in general much discussion about the meaning and validity of the intrinsic arguments, which are also dominant in the rejection of GMOs by the organic sector.

In ethical committees and public debates the emphasis is on the so-called extrinsic concerns: the risks for human health, for animals and for the environment. Most methods of risk analysis look only at the consequences and the effects of genetic engineering within the framework of a utilitarian ethics (weighing costs and benefits).

The intrinsic concerns deal with the technology itself rather than the consequences. Intrinsic objections are that genetic engineering is 'unnatural', or violating the dignity or integrity of plants and animals. These arguments are much more controversial, especially for those scientists and ethicists who consider extrinsic arguments to be more value-neutral and objective.

The intrinsic concerns, however, get more support from non-utilitarian ethicists, who refer to human virtues (virtue ethics). These virtues, such as humility and respect for (the intrinsic value of) nature or life, are important in people's basic attitudes towards nature. This ethics of integrity is related to a biocentric ethical theory, in which all living organisms have a value (good) of their own, related to their species-specific or characteristic 'nature'. To say that a living organism has intrinsic value means that it has a value, which goes beyond its instrumental value for human beings. A living organism should never be reduced to a mere object for human use, as if it would be morally indifferent. See Verhoog *et al*. (2004) for an overview of these different theories. In the next section we will describe why biocentric ethical theory and intrinsic concerns are central elements in the rejection of genetic engineering by organic agriculture.

Why organic agriculture rejects the use of GMOs

The International Federation of Organic Agriculture Movements (IFOAM 2002) is opposed to genetic engineering in agriculture in view of the unprecedented danger it represents for the entire biosphere and the particular economic and environmental risks it poses for organic producers. The reasons mentioned by IFOAM can be clustered into three groups:

1 Risks for human health and the environment
- negative and irreversible environmental impacts
- release of organisms that have never before existed in nature and which cannot be recalled
- pollution of off-farm organisms
- unacceptable threats to human health.

2 Socioethical reasons
- pollution of the gene pool of cultivated crops, microorganisms and animals
- denial of free choices, both for farmers and consumers
- violation of farmers' fundamental property rights and endangerment of their economic independence.

3 Incompatibility with the principles of sustainable agriculture.

Risks for human health and the environment

The rejection of GMOs in organic agriculture is based more on a different perception of risks than upon the presence or absence of scientific proof that risks exist objectively. The perception of risk from an organic perspective is based on a holistic view of life.

According to the IFOAM EU Group (2003), 'We also view this technology as inherently risky, because it is based on the reductionist scientific principles that have been shown to be flawed and are increasingly discredited'. Some of the reasons why genetic engineering is considered to be a risky technology by organic agriculture proponents include:

- The gene constructs used are synthetic constructs. The introduction of pure DNA would lead to its rejection by the receiving organism. The production of synthetic constructs is needed to have any effect. Whether they work or not is tested in a trial and error process.
- The low efficiency (rate of success) of the technology.
- The introduction of foreign DNA leads to many unintended and unexpected effects (Rist 2000).
- Genetic engineering (and the risk analysis, currently used by scientific committees) is influenced by the belief in genetic determinism, which is only part of the truth. Non-genetic, epigenetic influences during the development of the organism as a whole have shown to be as important as or even more important in some cases than the influence of DNA. The expression of DNA in the genome is much more dynamic than previously thought.
- Reductionist approaches to problems in agriculture are seen as symptomatic treatments. There is evidence of the resistance of insects to the pesticides used in combination with GMOs, or to *Bacillus thuringiensis* that is used in insect-resistant GMOs (Stix 1998, McDonald and Linde 2002).

It is the dynamic complexity of the organism or ecosystem as a whole that leads to unpredictability and unintended effects. The stability of the gene constructs and the controllability of the technology cannot be guaranteed. From a holistic point of view, genetic engineering is based on a way of thinking that is characteristic of the physicochemical sciences. By formulating the question of risks in terms of holistic risk perception, the argument turns from an extrinsic one into an intrinsic one.

Incompatibility with the principles of sustainable agriculture

This argument is problematic as long as these principles are not made explicit. Behind different meanings of sustainability are different views on the human relation to nature. The application of the industrial approach to living systems is felt to be 'unnatural' in organic agriculture, not fitted to the nature of living systems (Verhoog 2002/2003; Verhoog *et al.* 2003). In the industrial approach, the tendency is towards full control over nature (anthropocentric attitude); nature in some sense is eliminated. Its opposite is pristine nature, that is, untouched by human beings. But it is impossible to speak about 'pristine nature' in connection with agriculture, because every form of agriculture means interference in nature.

One way to describe the position of organic agriculture is to say that nature and culture are seen as two poles of a polarity relation, and both poles have to be cared for. We could call this the integration of nature and culture or agri-culture, but one that respects the independence, intrinsic value and autonomy of nature and of all living beings (biocentric approach). This manifests itself in various ways, which lead to further arguments against genetic engineering:

- The use of natural, rather than synthetic substances. The gene constructs put into organisms to create GMOs are synthetic constructs, not natural substances. The most important difference with traditional breeding is the direct interference in the genome of plants and animals by forcefully introducing artificial and synthetic gene constructs (that can only be created in an artificial environment *in vitro*). These gene constructs are human inventions. And in general (non-evolutionary time scales), the gene constructs contain genes that would never be transferred by natural means (transgenesis).
- Stimulation of the self-regulation of organisms and the ecosystem (using natural processes). In organic agriculture genetic engineering is seen as a technology that forces the organisms to do what humans want, instead of eliciting a reaction in which the natural entity retains its relative independence as a partner. Illustrative is the way humans have dealt with reproduction in the process of domestication of cows (and other domestic animals). Step by step (artificial selection – artificial insemination – embryo transplantation – genetic modification and cloning) the animal's own role in reproduction, its independence, is taken away from it and brought under human control (Verhoog 2003).
- Respect for the specific characteristics ('nature') or intrinsic value of plant and animal species, (agro-)ecosystems and landscapes. This is another reference to the acknowledgement of the independence of nature, but now at a moral level. In this moral context also the word 'integrity' is used. Lammerts van Bueren *et al.* (2003b) explained that the integrity of plants refers to their nature or way of being, their wholeness, completeness, their species-specific characteristics and their being in balance with the species-specific environment. When integrity refers to the specific 'nature' of plants (or animals), different levels of integrity can be distinguished: integrity of life, plant-specific integrity, genotypic integrity and phenotypic integrity. With this moral instrument the authors have assessed different plant breeding and propagation techniques, to find out whether they respect the integrity of plants. The outcome is that techniques at DNA level (e.g. protoplast fusion, genetic modification) violate all levels of the nature (integrity) of plants. The conclusion is that genetic engineering is not compatible with the intrinsic value of plants.

Our conclusion is that intrinsic arguments against genetic engineering are widely used in the field of organic agriculture. Such arguments usually rest upon a specific view of the human–nature relationship, which includes cognitive, emotive and volitional elements. Cognitive elements refer to a holistic (non-reductionist) view of living organisms. Emotive elements refer to a biocentric attitude towards life in which living organisms are seen as partners that should be respected, with an intrinsic value. The volitional elements refer to ethical statements as to what should or should not be done in organic agriculture, taking other elements into account.

Respecting the integrity of plants can also have consequences for the application of other modern breeding and propagation techniques for organic breeding and propagation programs (Lammerts van Bueren *et al*. 2003b; Lammerts van Bueren and Struik 2004). It may imply that:

- reproductive barriers between species will be respected and not violated;
- *in vitro* techniques are not compatible with organic principles;
- sterility, such as cytoplasmic male sterility, will not be accepted in the end product (variety) without including restorer genes; and
- patents on life are not accepted.

These considerations are not yet implemented in the Basic Standards for Organic Production and Processing of the International Federation of Organic Agriculture Movements and have only appeared as draft standards for 2002–2005 (see http://www.ifoam.org/about_ifoam/standards/norms/draft_standards/draft_standards.html).

The use of molecular markers in organic breeding programs

DNA diagnostic techniques, which enable selection at DNA level, do not involve genetic modification. The techniques, which are usually based on biochemical and molecular markers, could therefore be used in organic breeding programs to supplement trait selection methods in the field, but their potential for organic agriculture has yet to be proven. Genotype–environment interaction is of primary importance in organic plant breeding, and markers can, in addition to field selection, contribute to assessing environment-specific performance of genotype traits. However, a point of attention is the techniques used with DNA diagnostics, as some of them include the use of radioactive isotopes and (cancer-inducing) chemicals, which are not used or permitted in organic agriculture.

Conclusion: research for organic breeding concepts and strategies

To explore and develop plant breeding concepts and strategies, selection criteria and breeding techniques for better-adapted and reliable varieties for the organic sector, further research is needed. The question is how plant health characteristics such as nutrient uptake and use efficiency, weed suppression, disease tolerance, crop growth dynamic and yield stability interrelate under organic growing conditions, and to what extent such characteristics are genetically determined. But the question is also how such characteristics can be transformed into field selection criteria and what the role of molecular makers can be in organic breeding programs. Because of the logistical problems conventional breeding companies would like to know what the benefit is of selecting under organic growing conditions. Do organic farmers need specialist varieties adapted to specific regional conditions or generalists with less G × E interaction?

The limited area under organic production will be a bottleneck for economic interest in establishing specific breeding programs for organic farming systems, especially concerning small crops and low-yielding but important crops such as cereals and grain legumes. Governments should support public research and prebreeding activities. This also requires cooperation on an international level. In due time the variety requirements for the organic sector will meet the needs of conventional agriculture moving in a sustainable direction, thereby reducing the dependency on high chemical inputs, and will then enlarge the focus of the breeding industry in a low-input direction for modern agricultural development. Common areas for research among organic and conventional plant breeders include nutrient uptake and crop protection strategies.

References

Bonthuis, H., Donner, D.A. and Van Viegen, A. 2004. *80th List of Varieties of Field Crops 2005, Including Recommended List of Varieties 2005 and National List*. Stichting DLO, Wageningen.

Bullard, L, Geier, B, Koechlin, F., Leskin, D., Meister, I. and Verhagen, N. 1994. Organic agriculture and genetic engineering. *Ecology and Farming* 8: 25–26.

Ceccarelli S. 2000. Decentralized-participatory plant breeding: adapting crops to environments and clients. *Proceedings of the 8th International Barley Genetics Symposium, Adelaide 22–27 Oct. 2000, Volume 1.* Adelaide University, South Australia. pp. 159–166.

De Melo, P.E. 2003. The root systems of onion and *Allium fistulosum* in the context of organic farming: a breeding approach. PhD thesis, Wageningen University, the Netherlands.

Dornbusch, C., Schauder, A., Prior, P. and Köpke, U. 1992. Seed production in organic agriculture – improved criteria of seed quality in winter wheat. In: Köpke, U. and Schultz, D. (eds) *Proceedings of the 9th Conference of International Federation of Organic Agriculture Movements, Volume 1, Sao Paulo*. IFOAM, Tholey-Theley, Germany. pp. 19–24.

EFRC 2004. *Organic Cereal Varieties: the Results of Four Years of Trials*. Elm Farm Research Centre, Newbury.

Finckh, M.R., Gacek, E.S., Goyeau, H., Lannou, C., Merz, U., Mundt, C.C., Munk, L., Nadziak, J., Newton, A.C., De Vallavieille–Pope, C. and Wolf, M.S. 2000. Cereal variety and species mixtures in practice, with emphasis on disease resistance. *Agronomie* 20: 813–837.

Forsberg, G., Anderson, S. and Johnsson, L. 2000. Evaluation of hot, humid air seed treatment in thin layers and fluidized beds for seed pathogen sanitation. *Journal of Plant Disease and Protection* 109: 357–370.

Foulkes, M.J., Sylvester-Bradley, R. and Scott, R.K. 1998. Evidence for differences between winter wheat cultivars in acquisition of soil mineral nitrogen and uptake and utilisation of applied fertiliser nitrogen. *Journal of Agricultural Science* 130: 29–44.

Girsch, L. and Weinhappel, M. 2004. Specific seed health standards for organic cereal seed. In: Lammerts van Bueren, E.T., Ranganathan, R. and Sorensen, N. (eds) *Proceedings of the First World IFOAM/ISF/FAO Conference on Organic Seed – Perspectives, Challenges and Opportunities.* Rome, Italy, 5–7 July 2004. IFOAM, Bonn. pp. 79–83.

Groot, S.P.C., Oosterveld, P., Van der Wolf, J.W.M., Jalink, H., Langerak, C.J. and Van den Bulk, R.W. 2004. The role of ISTA and seed science in assuring organic farmers with high quality seeds. In: Lammerts van Bueren, E.T., Ranganathan, R. and Sorensen, N. (eds) *Proceedings of the First World IFOAM/ISF/FAO Conference on Organic Seed – Perspectives, Challenges and Opportunities.* Rome, Italy, 5–7 July 2004. IFOAM, Bonn. pp. 9–12.

Hagel, I., Bauer, D., Haneklaus, S. and Schnug, E. 2000. Quality assessment of summer and autumn carrots from a biodynamic breeding project and correlations of physico-chemical parameters and features determined by picture forming methods. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *Proceedings 13th International IFOAM Scientific Conference,* 28–31 August 2000, Basel. Hochschulverlag ETH, Zürich. pp. 284–287.

Henatsch, C. 2002. Organic farming needs organic plant breeding: a network for independent seed production and plant breeding. In: Thompson, R. (ed.) *Cultivating Communities. Proceedings of the 14th IFOAM Organic World Congress*. Victoria, Canada, August 2002. Canadian Organic Growers, Ottawa. p. 300.

Hospers, M. 1996. *Optimization of Biodynamic and Ecological Cultivation of Seed Potatoes*. Final report on research carried out between 1992 and1995. PAGV nr 210, Lelystad.

IFOAM 2002. *Position on Genetic Engineering and Genetically Modified Organisms*. IFOAM, Bonn.

IFOAM 2004. *Final Report from the First World Conference on Organic Seed*. <http://www.ifoam.org/events/reports/seed_conference.html>. Accessed 27/1/06.

IFOAM EU Group 2003. *Co-existence Between GM and Non-GM Crops*. Position Paper. Brussels.

ITAB 2001. *Agriculture Biologique: Guide 2001 des variétés de blé tendre. Resultats des essois de l'année preconisations*. Institut Technique de l'Agriculture Biologique (ITAB), Paris.

Jahn, M., Kromphardt, C., Forsberg, G., Werner, S., Wikström, M., Groot, S.P.C. and Rop, N. K. 2004. Control of seed-borne pathogens on vegetables by physical seed treatment methods. In: Lammerts van Bueren, E.T., Ranganathan, R. and Sorensen, N. (eds) *Proceedings of the First World IFOAM/ISF/FAO Conference on Organic Seed – Perspectives, Challenges and Opportunities.* Rome, Italy, 5–7 July 2004. IFOAM, Bonn. pp. 177.

Kitchen, J.L., McDonald, G.K., Shepherd, K.W., Lorimer, M.F. and Graham, R.D. 2003. Comparing wheat grown in South Australian organic and conventional farming systems. 1. Growth and grain yield. *Australian Journal of Agricultural Research* 54: 889–901.

Kunz, P., Beers, A., Buchmann, M. and Rother, J. 1995. Backqualität bei Weizen aus ökologischem Anbau. *Wissenschaften–Tagung Ökologische Landbau, Kiel. Beitrag* 3: 97–100.

Kunz, P. 2000. Sensorische Nahrungsqualität. *Lebendige Erde* 3: 27–28.

Lammerts van Bueren, E.T. and Struik, P.C. 2004. The consequences of the concept of naturalness for organic plant breeding and propagation. *NJAS–Wageningen Journal for Life Sciences* 52: 85–95.

Lammerts van Bueren, E.T., Struik, P.C. and Jacobsen, E. 2002. Ecological aspects in organic farming and its consequences for an organic crop ideotype. *Netherlands Journal of Agricultural Science* 50: 1–26.

Lammerts van Bueren ET, Struik PC and Jacobsen E. 2003a. Organic propagation of seed and planting material: an overview of problems and challenges for research. *NJAS– Wageningen Journal for Life Sciences* 51: 263–277.

Lammerts van Bueren, E.T., Struik, P.C., Tiemens-Hulscher, M. and Jacobsen, E. 2003b. The concepts of intrinsic value and integrity of plants in organic plant breeding and propagation. *Crop Science* 43: 1922–1929.

Lammerts van Bueren, E.T., Ranganathan, R. and Sorensen, N. 2004a. *Proceedings of the First World IFOAM/ISF/FAO Conference on Organic Seed – Perspectives, Challenges and Opportunities.* Rome, Italy, 5–7 July 2004. IFOAM, Bonn.

Lammerts van Bueren, E.T., Van Soest, L.J.M., De Groot, E.C., Boukema, I.W. and Osman, A. M. 2004b. Broadening the genetic base for better adapted varieties for organic farming systems: characterisation and assessment of onion accessions for new basic populations. In: *Proceedings of the XVIIth Eucarpia General Congress Genetic Variation for Plant Breeding.* 8–11 September 2004 Tulln, Austria. Eucarpia, Tulln. pp. 447–450.

Lemerle, D., Verbeek, B., Cousens, R.D. and Coombes, N.E. 1996. The potential for selecting wheat varieties strongly competitive against weeds. *Weed Research* 36: 505–513.

Mäder, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P. and Niggli, U. 2002. Soil fertility and biodiversity in organic farming. *Science* 296: 1694–1697.

McDonald, B.A. and Linde, C. 2002. The population genetics of plant pathogens and breeding strategies for durable resistance. *Euphytica* 124: 163–180.

Morris, M.L. and Bellon, M.R. 2004. Participatory plant breeding research: opportunities and challenges for the international crop improvement system. *Euphytica* 136: 21–35.

Nielsen, B.J. 2003. Threshold values for seed borne diseases of cereals and legumes. In: Lammerts van Bueren, E.T. and Wilbois, K.-P. (eds) *Organic Seed Production and Plant Breeding – Strategies, Problems and Perspectives, Proceedings of ECO–PB First International Symposium on Organic Seed Production and Plant Breeding*. Berlin, 21–22 November 2002. European Consortium for Organic Plant Breeding, Driebergen/Frankfurt. pp. 28–31.

Osman, A.M. and Lammerts van Bueren, E.T. 2002. A participatory approach to designing and implementing organic value for cultivation and use-research. In: Lammerts van Bueren, E.T. and Wilbois, K.-P. (eds) *Organic Seed Production and Plant Breeding – Strategies, Problems and Perspectives, Proceedings of ECO–PB First International Symposium on Organic Seed Production and Plant Breeding*. Berlin, 21–22 November 2002. European Consortium for Organic Plant Breeding, Driebergen/Frankfurt. pp. 46–50.

Peerenboom, R. 2004. Putting organic seed production in perspective. In: *Proceedings of the First World IFOAM/ISF/FAO Conference on Organic Seed – Perspectives, Challenges and Opportunities*. Rome, Italy, 5–7 July 2004. IFOAM, Bonn. pp. 6–8.

Ramos Garcia, M., Soriano, J.J. and Conzalvez, V. 2004. Organic seeds and biodiversity in Spain. In: *Proceedings of the First World IFOAM/ISF/FAO Conference on Organic Seed – Perspectives, Challenges and Opportunities*. Rome, Italy, 5–7 July 2004. IFOAM, Bonn. pp. 68–72.

Raupp, J. 1996. Yield patterns with organic or mineral fertilization. In: Kristensen, N.H. and Høgh–Jensen, H. (eds) *New Research in Organic Agriculture. Proceedings Volume 2*. 11th International Scientific IFOAM Conference, 11–15 August 1996, Copenhagen. IFOAM, Tholey-Theley, Germany. pp 62–69.

Rios Labrada, H., Soleri, D. and Cleveland, D.A. 2002. Conceptual changes in Cuban plant breeding in response to a national socio-economic crisis: the example of pumpkins. In: *Farmers, Scientists and Plant Breeding*, CAB International, New York. pp. 213–237.

Rist L. 2000. *Theoretische und experimentelle Untersuchungen über den Einfluss der Genmanipulation auf die Integrität der Arten*. Dissertation, Gesamthochschule Kassel.

Smith, B.J., Kirkegaard, J.A. and Howe, G.N. 2004. Impacts of Brassica break crops on soil biology and yield of following wheat crops. *Australian Journal of Agricultural Research* 55: 1–11.

Spiertz, J.H.J. 1989. Arable crop production. In: Zadoks, J.C. (ed.) *Development of Farming Systems. Evaluation of five year period 1980–1984*. Pudoc, Wageningen. pp. 19–25.

Stix, G., 1998. Resistance fighting. Will natural selection outwit the king of biopesticide? *Scientific American* 278: 21–22.

Stöppler, H., Kölsch, E. and Vogtmann, H. 1989. Auswirkungen der Züchtung bei Winterweizen in einem landwirtschaftlichen System mit geringer Betriebsmittelzufuhr von aussen. *Journal of Agronomy and Crop Science* 162: 325–332.

Sundrom, F.J. 2004. Progress on harmonisation of EU and US organic seed regulations. In: *Proceedings of the First World IFOAM/ISF/FAO Conference on Organic Seed – Perspectives, Challenges and Opportunities*. Rome, Italy, 5–7 July 2004. IFOAM, Bonn. pp. 26–27.

SUSVAR, 2004. *Minutes of the Working Group 6 (Variety Testing and Certification)*. <http://www.cost860.dk/workinggroups/WG6/doc/Minutes_WG6_Witzenhausen.doc>.

Tamm, L. 2000. The future challenge and prospects in organic crop protection. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *Proceedings 13th International IFOAM Scientific Conference*. 28–31 August 2000, Basel. Hochschulverlag ETH, Zürich. pp. 106–109.

Van der Zaag, D. 1999. *Die gewone aardappel – geschiedenis van de aardappel en de aardappelteelt in Nederland*. B. van der Zaag, Wageningen.

Van der Zeijden, D. 2004. The economic challenge for organic seed. In: *Proceedings of the First World IFOAM/ISF/FAO Conference on Organic Seed – Perspectives, Challenges and Opportunities.* Rome, Italy, 5–7 July 2004. IFOAM, Bonn. pp. 32–34.

Velema, J. 2004. Challenges and opportunities in organic seed production. In: *Proceedings of the First World IFOAM/ISF/FAO Conference on Organic Seed – Perspectives, Challenges and Opportunities.* Rome, Italy, 5–7 July 2004. IFOAM, Bonn. pp. 4–5.

Verhoog, H. 2002/2003. Biotechnologie und die Integrität des Lebens. *Scheidewege* 32: 119–141.

Verhoog, H. 2003. Naturalness and the genetic modification of animals. *Trends in Biotechnology* 21: 294–297.

Verhoog, H., Matze, M., Lammerts van Bueren, E. and Baars, T. 2003. The role of the concept of the natural/naturalness in organic farming. *Journal of Agricultural and Environmental Ethics* 16: 29–49.

Verhoog H. 2004. The reasons for rejecting genetic engineering by the organic movement. *Forum TTN (Technik, Theologie, Naturwissenschaften)* 12: 13–31.

Verhoog, H., Lund, V. and Alroe, H.F. 2004. Animal welfare, ethics and organic farming. In: Vaarst, M. Roderick S., Lund, V. and Lockeretz, W. (eds) *Animal Health and Welfare in Organic Agriculture*. CABI Publishing, Wallingford. pp. 73–94.

Welsh, J. and Wolfe, M.S. 2003. The performance of variety mixtures and the potential for population breeding in organic farming systems. In: Lammerts van Bueren, E.T. and Wilbois, K.-P. (eds) *Organic Seed Production and Plant Breeding – Strategies, Problems and Perspectives. Proceedings of ECO–PB First International Symposium on Organic Seed Production and Plant Breeding.* Berlin, 21–22 November 2002. European Consortium for Organic Plant Breeding, Driebergen/Frankfurt. pp. 40–45.

Welsh, J., Wolfe, M.S. and Morris, M. 2001. Cereal trials. *Organic Farming* 69: 14–15.

Williams, C.E. and St Clair, D.A. 1993. Phenetic relationships and levels of variability detected by restriction fragment length polymorphism and random amplified polymorphic DNA analysis of cultivated and wild accessions of *Lycopersicon esculentum*. *Genome* 36: 619–630.

Wolfe, M.S. 2003. Plant breeding, ecology and modern organic agriculture. In: Lammerts van Bueren, E.T. and Wilbois, K.-P. (eds) *Organic Seed Production and Plant Breeding – Strategies, Problems and Perspectives. Proceedings of ECO–PB First International Symposium on Organic Seed Production and Plant Breeding.* Berlin, 21–22 November 2002. European Consortium for Organic Plant Breeding, Driebergen/Frankfurt. pp. 18–24.

Special topic 2

Biodynamic agriculture today

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Introduction

Biodynamic agriculture can be described as a comprehensive agricultural system on mixed farms, which should always involve crops and livestock. The system is based on respect for, and efforts in, gaining awareness of the spiritual dimension of all creatures and the inorganic environment. Insights into this spiritual dimension (e.g. detailed descriptions of the spiritual character of animals, plants and physical elements or of planetary impacts) were given by Rudolf Steiner in 1924 (Steiner 2004). These descriptions should give farmers an orientation in their actions and awareness in order to evolve the agricultural system. Furthermore, the formulation of specific preparations was given by Steiner as a particular new element in agriculture. Biodynamic agriculture incorporates the landscape and the ecosystem as essential parts of the whole. It minimises nutrient inputs from outside the farm through proper legume crop management.

General principles in biodynamic farming

Globally, about 3270 holdings in 35 countries and with an area of 104,000 ha are certified under the *Demeter* label. This means that they comply with both the relevant national organic farming standards and the international Demeter Standards (Demeter International 2003). There are a huge variety of enterprises on Demeter farms, covering anything from temperate arable farming to viticulture in France, cotton production in Egypt and silkworm breeding in China.

The intentionally individual design of life processes by the farmer, as determined by site conditions, is one of the basic tenets of biodynamic agriculture. This principle emphasises that humans have a responsibility for the development of their ecological and social environment which goes beyond economic aims and the principles of descriptive ecology.

The vision on which this principle is based is the individual design of the holding in the context of the complex interaction of all impacting factors. The pedosphere, ecosphere and landscape, as well as the atmosphere and the cosmic environment (apart from the sun, these are primarily the moon and the planets) form the natural basis. Crop plants, livestock, the farmer as well as the entire socioeconomic environment have an effect at all levels of this natural environment, are influenced by these levels, and thus form an intricate interrelationship. A farm, therefore, becomes an ‘individuality’ in which the various factors, just like organs, have specific functions and are interlinked through feedback relationships. Biodynamic farming takes account of these interrelationships and tries to actively shape them into guided processes through a variety of management practices.

The prime objective is always to encourage healthy conditions for life. Soil fertility, plant and animal health, as well as product quality are to be maintained and continuously improved in a largely closed system by designing the individual farm enterprises and operations accordingly. The following principles are based on the above objective. They represent implicit targets of the biodynamic method which are to be implemented on the holdings (Demeter International 2003). The Demeter International trademark indicates that produce is grown and processed in compliance with their standards. Not all biodynamic farms or gardens are associated with *Demeter* as an organisation. For farms producing under the *Demeter* trademark, the following principles are compulsory. However, for other farms producing biodynamically, these principles are guides, but are not always binding.

Mixed holdings

Arable farming together with livestock is a prerequisite of biodynamic management. There are special regulations for horticultural enterprises and perennial crops. A variety of enterprises that balance out each other's one-sidedness are seen as a prerequisite for a healthy farm organism (Raupp 2000). The keeping of livestock, especially ruminants, is an essential element. Management largely aims at closed nutrient cycles. The use of mineral nitrogen (N) fertilisers is prohibited. Application of mineral calcium, potassium, phosphorous and magnesium fertilisers conforming to the Demeter Standards is permitted. It has been repeatedly shown that such management practices can indeed be sustainable (e.g. Kaffka and Koepf 1989, Reganold *et al.* 1993).

Varied site-appropriate crop rotations

A well-planned crop rotation is the basis for healthy plant growth and a fertile soil. Where crop rotations cannot be practiced (perennial crops e.g. fruit or grapevine), strips of cover crops with flowering plants are sown. A rhythmic alternation of nitrogen-fixing (e.g. legumes) and nitrogen-demanding plants (e.g. *Brassicas*), shallow-rooted (cereals) and deep-rooted plants (lucerne), soil-building (root crops) and soil-exhausting crops (cereals), or humus-building (fodder plants) and humus-destroying crops (root crops) utilises the effect of each preceding crop, enhances the formation of the soil structure and prevents crop rotation diseases. Legume cultivation for feed, as a grain legume or as green manure, is an indispensable part of the crop rotation (25–30%) in order to replace the required nitrogen (Koepf *et al.* 1976, Sattler and v. Wistinghausen 1992). An ideal crop rotation maintains a year-round green cover, improving soil fertility in the most sustainable manner, and preventing nutrient losses.

Intensive organic fertilisation

Fertilisation does not aim primarily at feeding the plants but at enlivening the soil. This basic tenet of biodynamic farming requires intensive fertilisation using farmyard manure, composts, liquid manure, green manure and others. The use of farm-generated fertilisers varies with the crop grown and is targeted at growing high quality foods. For example, potatoes are given farmyard manure; vegetables receive only well-rotted composts. Organic fertilisers are treated with biodynamic compost preparations (see *Biodynamic preparations*) as standard practice in order to enliven the fertiliser as well as the soil. Regular applications of organic fertilisers serve to close and intensify nutrient cycles (Koepf *et al.* 1976).

Biodynamic preparations

To support and intensify the processes in the organic manure and in the soil, Steiner indicated six different preparations that should be added together to the manure (Sattler and v. Wistinghausen 1992, Steiner 2004 5th lecture). Furthermore, Steiner (2004) introduced two field-spray preparations that are used to support fertility and plant development at certain growth stages (Steiner 2004, 4th lecture). The compost preparations (formerly preparations 502–506) are all made from medicinal plants: yarrow flowers (*Achillea millefolium*), chamomile flowers (*Chamomilla recutita*), whole plant of stinging nettle (*Urtica dioica*), oak bark (*Quercus robur*), dandelion flowers (*Taraxacum officinale*) and valerian flowers (*Valeriana officinalis*). In most cases, these are stored in certain animal organ 'sheaths' (intestine, peritoneum, bladder) and fermented for a certain time buried in the soil or under the influence of air. The two field sprays are cow manure ('horn manure', formerly preparation 500) and quartz meal ('horn silica', formerly preparation 501), both buried in the soil in cow horns, horn manure during the winter, horn silica during the summer. After they have been dissolved in water and stirred rhythmically for one hour, these substances are sprayed on plants and soil (see also Raupp and König 1996, Wistinghausen *et al*. 1998).

Livestock husbandry systems which fulfil the animals' welfare requirements

Livestock husbandry, which is based on regarding the animals as beings with souls (Kremer 2002) results in stricter standards than are normally applied. For example, the dehorning of cows is prohibited; breeding for isolated performance criteria is avoided (Baars *et al*. 2003) and the aim is to breed for longevity and lifetime yield. In this type of livestock husbandry ruminants, for example, are regarded as animals whose role is to utilise roughage. Breeding aimed at high milk yields, which can only be sustained with high concentrate inputs, is considered adverse to the animals' welfare requirements. From the point of view of maturity, heifers for example, should be given sufficient time to develop prior to being put in calf for the first time.

Food quality – the stuff of life

The production of high-quality food for people and animals is an implicit aim of the biodynamic method (Steiner 2004, 4th lecture). The question as to how food quality can be defined is challenging for both practitioners and researchers, and has led to intensive development on quality assessment methods. Great importance is attached to differentiation and ripening processes in the production and processing of foods.

Breeding locally adapted crop plant varieties

Only biodynamic farming currently has its own organic plant-breeding programs, which aim to provide varieties that are suited to biodynamic cultivation and are efficient in their management. This field of action is a key issue for biodynamic agriculture. In terms of breeding objectives, the priorities are plant health, suitability of the respective environmental conditions, the ability to save seed and propagate them on-farm, as well as high food quality and yield (Müller *et al*. 2000, ABDP 2003).

Maintaining plant health

Starting with the use of plant protectants and management agents in accordance with biodynamic standards, biodynamic farming uses further specific preparations. Steiner (1924, 6th lecture) recommended spraying horsetail tea (*Equisetum arvense*), in addition to the 'stimulating' preparations, to protect crops from fungal diseases. For pest regulation, the ashes of burnt specimens of the pest species are to be used (Bächi-Kunz 1985).

Cosmic rhythms

The annual rhythms and the rhythms of the moon, as well as those of the planets, are considered in sowing, planting, and harvesting and sometimes also for fertiliser applications (Steiner

2004, 1st and 6th lecture, Spiess 1990ab, Goldstein and Barber 2000, Spiess 2000, Thun and Thun 2004).

Low-impact soil management

Soil cultivation measures are predominantly carried out with the aim of enhancing soil fertility and soil processes, and controlling for weeds. Depending on location and crop type, biodynamic farming uses all types of soil cultivation from ploughing to no-till agriculture.

Including the landscape

Landscape design as an element of farm management has always been considered in biodynamic farming (Steiner 2004, 7th lecture). There is a growing awareness of the role of landscape design at the farm level (Bockemühl 1992, van Steensel 2000, York 2002).

Design of the social and economic setting

The concept of land ownership is increasingly being questioned on biodynamic farms and the land is no longer necessarily regarded as private property. Often it is transferred to charitable trusts or similar organisations. Ways that aim to build economic relationships between producers and consumers based on the principles of mutual responsibility and respect are being pioneered. Agricultural work is also regarded as a therapeutic opportunity, and mentally handicapped or spiritually ill people, troublesome youngsters, addicts, and convicts are often integrated into the farm communities. The training of apprentices is of high priority, and in many countries there are comprehensive training courses or agricultural colleges that specifically teach biodynamic farming methods. Regular courses and seminars for working farmers are another field that is given much attention.

These guidelines leave much scope for each individual farm to work out its own strategy congruent with the living conditions in its surroundings. The farm individuality, to which much importance is attached (Steiner 2004), results from this detailed design. The manner of soil cultivation, the exact design of crop rotations, fertilisation regimes, choice of varieties, the apportionment of livestock categories, the balance between enterprises, the nature of social relationships on the farm and economic relationships with the customers are all-incumbent on the farmers and are not regulated. However, they are documented as part of the national *Demeter* inspections and are discussed and evaluated in professional journals, at regular association meetings and at an annual international conference in Switzerland (Goetheanum 2004).

Background – what are the roots of biodynamic farming?

The concepts underlying biodynamic agriculture relate in particular to the spiritual radiance of all earthly phenomena, including that of the inorganic pedosphere and the cosmos. The physical–sensory reality is seen as an expression of the diversely structured spiritual world, the development of which takes place through the processes in the physical world. However, this idea of development is not strictly teleological, as it regards human beings as active creators of future developments both in the positive and the negative sense. Therefore, the biodynamic concept of ecology is not a conserving but a developing one.

These views are based on anthroposophy, a multifarious worldview, inspired by Rudolf Steiner (1861–1925) with the core opinion that any thing, any occurrence in the world has its cause in a spiritual world that is actually present and can fundamentally be an object of human awareness. Anthroposophy, insofar as it concerns the perception of nature, understands itself as giving an additional dimension, the spiritual one, which in no case would replace or deny any basic natural law. The way to develop the ability to attain knowledge of this spiritual world through the awareness of the sensory world, and the manner in which this spiritual world acts and appears, was described by Steiner in many books and lectures. Two central works are Steiner (1997) and Steiner (1999). The biodynamic farming system was founded in June 1924, when Steiner met with about 60 farmers in Koberwitz near Wroclaw (Poland) and gave eight lectures about a modern agriculture based on spiritual science (Steiner 2004). Today these eight lectures still form the essential and formative basis of biodynamic farming, with much practical and scientific experience during the past 80 years having more closely defined and evolved many aspects of this foundation. Steiner gave these lectures at the request of farmers who were involved in the development of anthroposophy, and when he gave the Koberwitz lectures, in agreement with his listeners, he based his deliberations on previous lectures.

Research – what are the main questions faced by biodynamic farmers and researchers?

Biodynamic research is often associated with research on the preparations and cosmic influences (Kirchmann 1994, Trevawas 2004). In the early days, much scientific attention was indeed given to the preparations (Koepf 1993, Goldstein 2000, IBDF 2003). Many attempts have been made to provide evidence for the effect of the preparations on soil parameters (e.g. Bachinger 1995, Carpenter-Boggs *et al.* 2000, Mäder *et al.* 2002), plant development (Koppenol 1999), root growth intensity (Figure 1) (König 2002) and food quality (IBDF 2003). Results vary widely (Koepf 1993, Goldstein 2000). However, most of the studies assess the overall impact of the biodynamic method, of which the use of the preparations is but one part.

Some studies, including more prominent ones (Reganold *et al.* 1993, Mäder *et al.* 2002), have repeatedly shown a clearly positive impact of the biodynamic method on soil structure, enzyme activities, CO_2 exchange and earthworm populations (Koepf 1993, Goldstein 2000). However, there are also studies that were not able to show such results (Carpenter-Boggs *et al.* 2000). With regard to plant development, the aim is to achieve a compensating, stabilising effect that levels out extremes (Steiner 2004), and these effects have repeatedly been observed (Koepf 1993, Raupp and König 1996, Koppenol 1999). The impact of cosmic rhythms on plant growth has been verified many times (Kolisko and Kolisko 1939, Spiess 1990ab, Goldstein and Barber 2000, Spiess 2000, Zürcher 2001, Thun and Thun 2004); however, no conclusive explanation of the reasons for the variation in the results has yet been produced (see also Spiess, 1990ab, Kollerstrom and Staudenmaier 2001).

Essential research focuses on plant breeding (Müller *et al.* 2000, Henatsch 2002, Lammerts van Bueren 2002, ABDP 2003), appropriate breeding objectives for livestock (Baars *et al.* 2003), the veterinary treatment of livestock (Walkenhorst *et al.* 2004), ruminant feeding with low concentrate inputs, food quality and food quality evaluation methods (Selawry and Selawry 1957, Balzer-Graf 1987, Strube and Stolz 2000).

It is necessary to drive forward research on the effectiveness of the biodynamic preparations in order to provide sound practical recommendations for the frequency and timing of their use. However, discussions are required to decide whether it makes sense to assess the effect of individual biodynamic practices in isolation from the overall method, as these practices were proposed as part of a comprehensive farming system (Steiner 2004), the impulse of which is based, in particular, on a holistic understanding of agricultural processes. A complex, holistic, systemic form of science would be appropriate to biodynamic farming (Baars 2002), but has not yet been realised (Lockeretz 2000). It is unclear what would constitute holistic research. Phenomenological descriptions of the overall context are without doubt a key element that has been developed in much detail in the context of anthroposophic research over the past 80 years (Bockemühl 1992). However, does holistic research mean that the approach to every

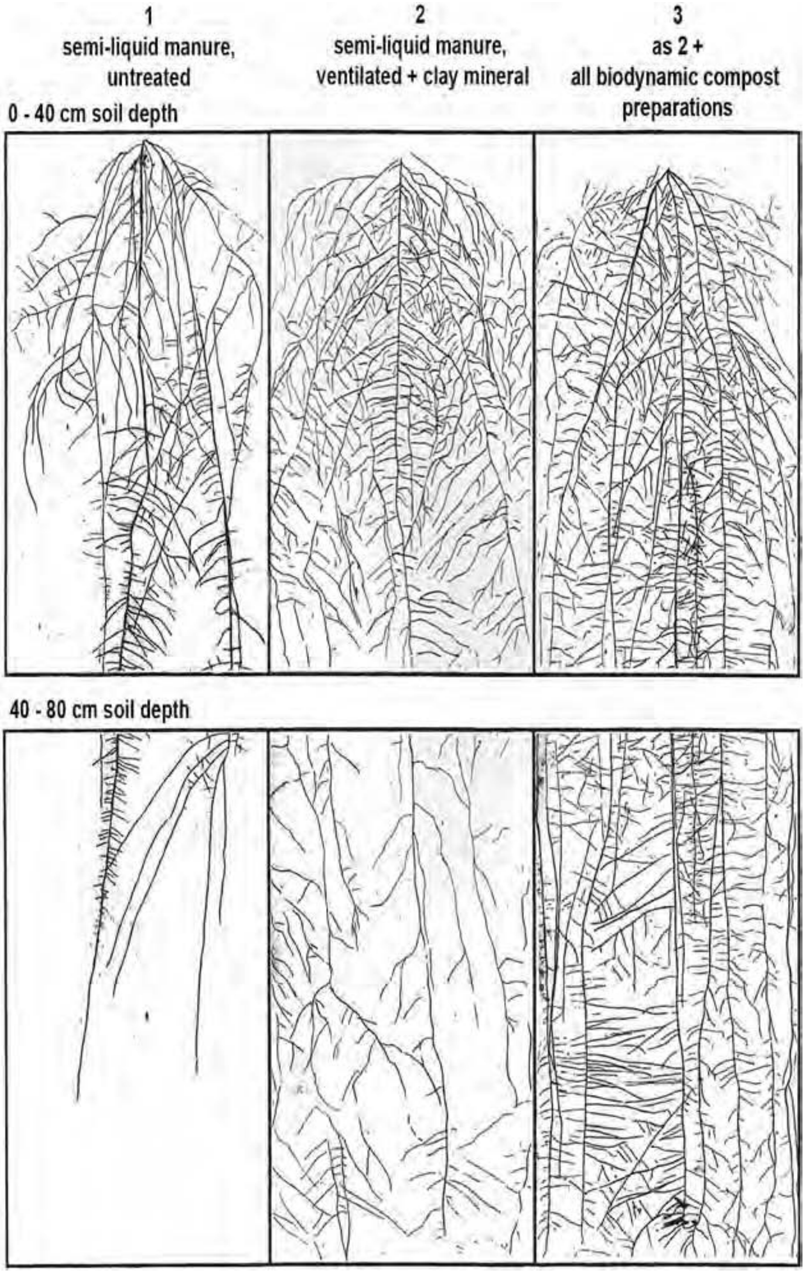

Figure 1 Influence of prepared and unprepared semi-liquid manure of the root growth of bush beans (*Phaseolus vulgaris*) (Abele 1978).

study must be to assess a comprehensive whole, or is it based on interdisciplinary research and on the overall review of results from individual, possibly isolating studies (see also Baars 2002, Holdrege 2002)? How can the farmer's experience be integrated effectively (Baars *et al.* 2004)? How can experiences made under very individual and regionally specific conditions be generalised? These questions are fundamental future research fields and they are also essential to the discourse with classical science.

Finally, biodynamic scientists are also charged with developing a continuous dialogue between biodynamic science and the natural sciences *sensu stricto*. The issues here are important questions of paradigms, differing world views and value systems, that need to be clearly communicated. Occasionally individual scientists strongly criticise biodynamic research and deny it any scientific credibility (Kirchmann 1994, Trevawas 2004). These criticisms are not in keeping with the facts, however, as they take no notice of large areas of biodynamic management and research, although they are also rooted in an unresolved conflict of world views. One challenge for biodynamic science will be to articulate and convincingly tackle this problem (*cf.* Dürr 2001).

References

ABDP 2003. *Mission Statement*. Association of Biodynamic Plant Breeders, Neu Darchau. <http://www.abdp.org/index_en.htm>. Accessed 21/8/05.

Abele, U. 1978. *Ertragssteigerung durch Flüssigmistbehandlung. Untersuchung des Rotteverlaufs von Gülle bei verschiedener Behandlung und deren Wirkung auf Boden, Pflanzenertrag und Pflanzenqualität*. Kuratorium für Technik und Bauwesen in der Landwirtschaft, Darmstadt.

Baars, T. 2002. Reconciling scientific approaches for organic farming research. PhD thesis, Wageningen Agricultural University.

Baars, T., Spengler, A. and Spranger, J. 2003. Is there something like bio-dynamic breeding? *Paper presented at the workshop: Initiatives for animal breeding in organic farming in Europe and evaluation for future strategies; 17/18 October 2003 at the Louis Bolk Institute, Driebergen, The Netherlands.* <http://orgprints.org/3268/>. Accessed 21/8/05.

Baars, T., Veltman, L. and van Eekeren, N. 2004. Farmer's experiences and scientific on-farm experimentation in an experiential science approach. *Grassland Science in Europe* 9: 1181–1183.

Bachinger J. 1995. Effects of organic and mineral fertilizer on chemical and microbial parameters of C- and N-dynamics and root parameters. In: Mäder P. and Raupp, J. (eds) *Effects of Low and High External Input Agriculture on Soil Microbial Biomass and Activities in View of Sustainable Agriculture, 2nd Meeting of the EU-Concerted Action (AIR3-CT94-1940).* Oberwil, Switzerland, September 15–16, 1995. Forschungsinstitut für biologischen Landbau, Oberwil, pp. 52–58.

Bächi-Kunz, R.C. 1985. *Untersuchungen über die Anwendung der Veraschung nach R. Steiner (1924. im Zusammenhang mit kosmischen Konstellationen am Beispiel von Tribolium castaneum Herbst (Col.: Tenebrionidae)*. PhD thesis, Swiss Federal Institute of Technology, Zürich.

Balzer-Graf, U. 1987. Vitalaktivität von Nahrungsmitteln im Spiegel bildschaffender Methoden. *Elemente der Naturwissenschaft* 46: 69–92.

Bockemühl, J. 1992. *Awakening to Landscape.* The Goetheanum, Dornach.

Carpenter-Boggs, L., Kennedy, A.C. and Reganold, J.P. 2000. Organic and biodynamic management: effects on soil biology. *Soil Science Society of America Journal* 64: 1651–1659.

Demeter International 2003. *Production Standards.* Demeter International, Darmstadt. <http://demeter.net/standards/st_production_e04.pdf>. Accessed 21/8/05.

Dürr, H.P. 2001. Unbelebte und belebte Materie: Ordnungsstrukturen immaterieller Beziehungen – Physikalische Wurzeln des Lebens. In: Reents, H.J. (ed.) *Proceedings 6th Conference for Science in Organic Agriculture*. Köster, Berlin. pp. 17–30.

Goetheanum. 2004. *Tagungen.* The Goetheanum, Dornach. <http://www.sektion-landwirtschaft.org/571.html>. Accessed 21/8/05.

Goldstein, W. 2000. Experimental proof for the effects of biodynamic preparations. *Biodynamics* 231: 6–13.

Goldstein, W. and Barber, B. 2000. The effects of planting dates and lunar positions on the yield of carrots. *Biodynamics* 230: 13–17.

Henatsch, C. 2002. Could genetic engineering be part of a sustainable breeding approach? In: Heaf, D. and Wirz, J. (eds) *Genetic Engineering and the Intrinsic Value and Integrity of Animals and Plants.* Ifgene, Llanystumdwy. pp 53–57.

Holdrege, C. 2002. Seeing the integrity and intrinsic value of animals: developing appreciative modes of understanding. In: Heaf, D. and Wirz, J. (eds) *Genetic Engineering and the Intrinsic Value and Integrity of Animals and Plants.* Ifgene, Llanystumdwy. pp. 18–23.

IBDF 2003. *The Biodynamic Preparations.* Institut für biologisch–dynamische Forschung, Darmstadt and Bad Vilbel. <http://www.ibdf.de/bdprepe.htm>. Accessed 21/8/05.

Kaffka, S. and Koepf, H.H. 1989. A case study on the nutrient regime in sustainable farming. *Biological Agriculture and Horticulture* 6: 89–106.

Kirchmann, H. 1994. Biological dynamic farming – an occult form of alternative agriculture? *Journal of Agricultural and Environmental Ethics* 7: 173–187.

Koepf, H.H. 1993. *Research in Biodynamic Agriculture, Methods and Results.* Biodynamic Farming and Gardening Association, Kimberton.

Koepf, H.H., Pettersson, B.D. and Schaumann, W. 1976. *Bio-dynamic Agriculture*. Anthroposophic Press: Hudson, New York.

Kolisko, E. and Kolisko, L. 1939. *Agriculture of Tomorrow.* Kolisko Archives, Edge.

Kollerstrom, N. and Staudenmaier, G. 2001. Evidence for lunar-sidereal rhythms in crop yield: a review. *Biological Agriculture and Horticulture* 19: 247–259.

König, U.J. 2002. Rückblick auf 25 Jahre Präparateforschung am Beispiel der Lichtwirkung der Präparate. *Schriftenreihe Institut f]ü]r Biologisch-dynamische Forschung* 16: 39–44.

Koppenol, M. 1999. Why use preparation 501 on the sunny, warm east coast? *Harvests* 52: 9–12.

Kremer, H.J. 2002. Understanding the cow: aspects relating to the nature of the bovine animal. *Biodynamics* 240: 14–18.

Lammerts van Bueren, E.T. 2002. *Organic Plant Breeding and Propagation: Concepts and Strategies*. PhD thesis, Wageningen Agricultural University.

Lockeretz, W. 2000. Organic farming research, today and tomorrow. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *Proceedings of the 13th International IFOAM Scientific Conference.* Hochschulverlag ETH, Zurich. pp. 718–720.

Mäder, P., Fließbach, A., Dubois, D., Gunst, L., Fried, P. and Niggli, U. 2002. Soil fertility and biodiversity in organic farming. *Science* 296: 1694–1697.

Müller, K.J., Kunz, P., Spiess, H., Heyden, B., Irion, E. and Karutz, C. 2000. An overnational cereal circuit for developing locally adapted organic seeds of wheat. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *Proceedings of the 13th International IFOAM Scientific Conference.* Hochschulverlag ETH, Zurich. p. 224.

Raupp, J. 2000. The well-proportioned farm organism. Just a pleasing image of a mixed farming system or rather a basic requirement for functioning organic husbandry? In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *Proceedings of the 13th International IFOAM Scientific Conference.* Hochschulverlag ETH, Zurich. pp. 700–703.

Raupp, J. and König, U.J. 1996. Biodynamic preparations cause opposite yield effects depending upon yield levels. *Biological Agriculture and Horticulture* 13: 175–188.

Reganold, J.P., Palmer, A.S., Lockhart, J.C., and Macgregor, A.N. 1993. Soil quality and financial performance of biodynamic and conventional farms in New Zealand. *Science* 260: 344–349.

Sattler, F. and Wistinghausen, E.v. 1992. *Bio-dynamic Farming Practice*. Biodynamic Agricultural Association, Stoubridge.

Selawry, A. and Selawry, O. 1957. *Die Kupferchloridkristallisation in Naturwissenschaft und Medizin*. Fischer, Stuttgart.

Spiess, H. 1990a. Chronobiological investigations of crops grown under biodynamic management. I. Experiments with seeding dates to ascertain the effects of lunar rhythms on the growth of winter rye (*Secale cereale*, cv. Nomaro). *Biological Agriculture and Horticulture* 7: 165–178.

Spiess, H. 1990b. Chronobiological investigations of crops grown under biodynamic management. II. Experiments with seeding dates to ascertain the effects of lunar rhythms on the growth of little radish (*Raphanus sativus*, cv. Parat). *Biological Agriculture and Horticulture* 7: 179–189.

Spiess, H. 2000. Lunar rhythms and plants. *Biodynamics* 229: 19–22.

Steiner, R. 1997. *An Outline of Esoteric Science.* Rudolf Steiner Press, London.

Steiner, R. 1999. *Philosophy of Freedom. The Basis for a Modern World Conception.* Rudolf Steiner Press, London.

Steiner, R. 2004. *Agricultural Course. The Birth of the Biodynamic Method.* Rudolf Steiner Press, London.

Strube, J. and Stolz, P. 2000. Fluorescence excitation spectroscopy for the evaluation of seeds. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *Proceedings of the 13th International IFOAM Scientific Conference.* Hochschulverlag ETH, Zurich. pp. 306–309.

Thun, M. and Thun, M.K. 2004. *The Biodynamic Sowing and Planting Calendar.* Floris Books, Edinburgh.

Trewavas, A. 2004. A critical assessment of organic farming-and-food assertions with particular respect to the UK and the potential environmental benefits of no-till agriculture. *Crop Protection* 23: 757–781.

van Steensel, F. 2000. Biodynamic farming and ecology. *Harvests* 53: 11–16.

Walkenhorst, M., Notz, C., Klocke, P., Spranger, J. and Heil, F. 2004. Udder health concepts that comply with organic principles – how to reduce therapies? In: Hovi, M., Sundrum, A. and Padel, S. (eds) *Proceedings of the 2nd SAFO Workshop.* SAFO Sustaining Animal Health and Food Safety in Organic Farming, Reading. pp. 71–75.

Wistinghausen, C.v., Scheibe, W., Wistinghausen, E.v. and König, U.J. 1998. *The Biodynamic Spray and Compost Preparations – Production Methods. Booklet No. 1. Stroud, 1. Edition*. Biodynamic Agricultural Association, Stoubridge.

York, A. 2002. The cultured landscape. *Biodynamics* 239: 9–14.

Zürcher, E. 2001. Lunar rhythms in forestry traditions – lunar-correlated phenomena in tree biology and wood properties. *Earth Moon and Planets* 85: 463–478.

Chapter 6

Organic livestock husbandry and breeding

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Introduction

The aims of this chapter are to give a short overview about organic animal husbandry in general and to discuss problems of organic animal housing and breeding in more detail. Animal husbandry could be regarded as the complete field of animal farming. In a narrower sense, housing of animals is considered.

Publications about organic animal husbandry in peer-reviewed journals are relatively scarce. According to Nicholas *et al.* (2004), from 472 refereed publications identified in 1981 to 2000, only 9% were on animal related topics. Lund and Algers (2001) found only 22 papers about health and welfare in the ten years from 1991. Furthermore, sample sizes included were often relatively small and comparisons with conventional farms have not always been done according to these authors.

Scientific literature about organic animal husbandry is generated almost completely from Europe (mainly United Kingdom, UK, and Scandinavia) or North America. Many agricultural systems in developing countries are often organic as a consequence of limited resources and availability of modern technologies. However, information about such systems is not included in this review because of lack of clear definitions. Certified organic production in developing countries is mostly export oriented, and mainly includes products from plant origin (e.g. coffee, tea, cacao, oil, citrus fruits, bananas, tropical fruits, spices) (Willer and Yussefi 2004). Organic livestock production is still a relatively new concept in Asia; however, some Latin American countries are starting to export organic meat products (Pathak *et al.* 2003). The main part of organic agriculture in Australia, however, is based on extensive grazing areas. The same is true for Argentina (Willer and Yussefi 2004). In 14 out of 16 European countries, livestock products were within the top five organic products (Hermansen 2003).

The European Union (EU)-funded Network on Animal Health and Welfare in Organic Agriculture (NAHWOA) held five workshops between 1999 and 2001 concerning topics like diversity of livestock systems, human–animal relationships, feeding and breeding, health management, and have published final conclusions and recommendations (www.veeru.reading.ac.uk/organic). A further activity of the network was the publication of a scientific book *Animal Health and Welfare in Organic Agriculture* (Vaarst *et al.* 2004). Another EU funded Concerted Action Project is Sustaining Animal Health and Food Safety in Organic Farming (SAFO) (www.safonetwork.org) with a focus at food quality. As in the NAHWOA network, the main activity is scientific exchange, assisted by five workshops held between 2003 and 2005. Further conferences have been held in Europe on some topics of organic livestock farming (e.g.

Hermansen *et al.* 2000, Thamsborg *et al.* 2000, Younie and Wilkinson 2001, Kyriazakis and Zervas 2002).

Willer and Yussefi (2004) provide information about the state of organic agriculture worldwide. However, the data presented mainly deal with the number of farms and the size and respective percentage of land under organic management. Information about the volume of animal production is lacking. Foster and Lampkin (2000) published some data about certified organic livestock in Europe between 1993 and 1998 (dairy cows, other cattle, pigs, poultry, sheep, goats), but not in relation to farm sizes.

Percentages of organically kept animals presumably differ between animal species, at least in countries with intensive animal production. In Germany for example, 17% of all beef cows were kept organically in the year 2002, 8% of sheep, 7% of geese, but less than 2% of pigs or other poultry species (Goessler 2004). Similar tendencies were found in 1998 for other European countries (Foster and Lampkin 2000). Pigs and poultry are kept more intensively under conventional production (e.g. stocking densities, housing conditions, feed origin). These farms have thus more difficulties converting to organic agriculture. Beef or sheep farms are often managed relatively extensively so that they can be converted more easily.

The International Federation of Organic Agriculture Movements (IFOAM) standards are valid for all member organisations and the farmers belonging to them (IFOAM 2002). These standards include the general principles, minimum requirements, recommendations and derogations (i.e. formal substitution of an organic input with a conventional input where no organic input can be found). The IFOAM standards provide a framework for regulation; therefore, member organisations can pass stronger guidelines. Another type of a more general standard is the Codex Alimentarius of the Food and Agriculture Organization (FAO) of the United Nations (Joint FAO-WHO Food Standards Programme 1999). The EU regulations concerning organic livestock production (EUR-Lex 1999, 2003) are obligatory for all producers in EU countries that want to sell their livestock products as 'organically produced'. All countries that intend to export organic products to the EU must meet these requirements.

Standards for organic animal husbandry have not been considered as explicitly by the organic movement as the standards for organic plant production. This could be explained by the organic movement having started with soil and plant production ('produce healthy plants on healthy soils').

Housing

Livestock housing can be defined as 'the way that animals are accommodated on a farm'. This can include both stables or pasture systems. In a broader sense, housing covers all factors that could influence the animal, including handling by humans, transport and slaughtering. Furthermore, influences from animal housing on the environment are considered, especially pollution.

An overview of animal welfare in organic farming by Vonne Lund is presented elsewhere (see *Chapter 8*). Animal welfare is reduced in conventional intensive housing systems because of high densities and lack of stimuli like straw, and this may lead to behavioural disturbances, injuries or some diseases. Livestock housing on organic farms should allow for the behavioural requirements of different farm animal species, facilitate efficient management, and use environmentally friendly construction materials and methods.

It is possible to draw some conclusions from the natural behaviour of farm animals to determine the most appropriate housing conditions (Tables 6.1–6.3).

Table 6.1 Species-specific behaviour of cattle with regard to adequate housing systems (Fölsch and Hörning 1996, Hörning 1998)

Functional unit	Species-specific behaviours	Appropriate housing
Social behaviour	Herd animals Feed or rest at same time Avoidance distances	Loose housing systems 1 feeding and 1 resting place per cow Wide passages, sufficient space
Feeding	Several feeding periods per day Competition for food Drinking by suction	Ad libitum feeding Feeding barriers Drinking troughs
Locomotion	Need to move Walking on soft ground	Loose housing, exercise yard, pasture Combination of hard flooring and littered areas
Resting behaviour	Lying on soft ground Species-specific raising and lying down	Litter Flexible side partitions of cubicles
Comfort behaviour	Rubbing, licking	Rubbing brushes in loose housing systems

Table 6.2 Species-specific behaviour of pigs with regard to adequate housing systems (Fölsch and Hörning 1996, Hörning 1998)

Functional unit	Species-specific behaviours	Appropriate housing
Social behaviour	(Mother-)family groups Differentiated social behaviour	Group housing, small groups Structured pens, sufficient space
Mother–offspring interactions	Isolation during farrowing Construction of farrowing nests	Separate farrowing pens Farrowing without fixation, provision of nesting material
Exploratory behaviour	Distinct exploratory behaviour Rooting with the snout	Rich and diverse environment Provision of materials for rooting
Locomotion	Need to move	Outdoor run, pasture
Feeding	Omnivores Distinct forage seeking behaviour Competition for food	Diverse diet Provision of roughages Separations at the trough
Eliminative behaviour	Separation of resting and defecation	Separate resting and dunging areas
Comfort behaviour	Rubbing Wallowing	Rubbing brushes or trees Opportunity for cooling down (wallow, shower)
Resting behaviour	Shelter	Solid side walls

Table 6.3 Species-specific behaviour of chickens with regard to adequate housing systems (Fölsch and Hörning 1996; Hörning 1998)

Functional unit	Species-specific behaviours	Appropriate housing
Feeding	Scratching and pecking Intake of plant material	Littered area for scratching, feeding grains in the litter Supply of roughage, access to pasture
Locomotion	Walking, flying, fluttering	Enough space, elevated perches
Resting behaviour	Roosting in trees	Elevated perches
Social behaviour	Small groups including cocks	Division into groups, add cocks
Egg laying	Sheltered location Nest building	Shaded nests Littered nests (e.g. using chaff)
Comfort behaviour	Dust bathing Sun bathing	Supply dust bath Natural lighting

Possible conflict areas

Regulations

The IFOAM standards and the EU regulations contain some sections concerning housing. In general, the organic standards require that housing conditions must meet the livestock's normal biological and ethological needs (IFOAM 2002). The animals must be kept in group housing because they are social living beings. They must have organic material for recreation and other purposes (e.g. lying on soft ground). Therefore, the housing systems commonly used in conventional agriculture like tying stalls for cattle, crates for sows, fully slatted pens for growing cattle or growing pigs and battery cages for laying hens are forbidden.

Furthermore, the animals must have access to outside areas, either to an outdoor run or to pasture. This offers additional space and contact with climatic stimuli (sun, rain, wind). In most intensive housing systems, farm animals will never have any access to the outside. The EU regulation contains minimum space requirements for the stable and the outside area. In intensive animal production, animals are sometimes mutilated (e.g. beak trimming, tail docking, teeth clipping, dehorning) to reduce the negative effects of intensive housing conditions. Although the symptoms of intensive housing are removed, the causes remain. In organic agriculture, mutilations should be avoided or restricted to a minimum (and allowed only as an exception). However, some people argue that some mutilations are necessary in alternative housing systems. For example, rooting of pigs at pasture could destroy the vegetation. Nose ringing reduces pasture damages. However, nose ringing severely hinders the species-specific behavioural need and could lead to injuries. Feather pecking may be a bigger problem in large groups of laying hens that are common in alternative housing systems. Beak trimming is a severe intervention into the physical intactness of the animal. Therefore, appropriate management measures are very important to avoid such mutilations in alternative housing systems.

The aforementioned regulations for organic livestock housing offer good preconditions for animal welfare. They can be regarded, and this should be communicated to consumers, as strong principles, similar to the ban of pesticides in plant production. Literature on the distribution of housing systems in organic agriculture in different, primarily English-speaking countries is scarce. However, housing systems seem to differ considerably between countries. For example, in Austria organic pigs are normally housed indoors with an access to an outside run (mostly with a solid concrete floor) for fattening pigs and gestating sows, but not for farrowing sows and weaners (Baumgartner *et al.* 2003). Similar conditions exist in the Netherlands or Germany (Vermeer *et al.* 2000, Winckler *et al.* 2001). In contrast, a small sample from England has shown that organic pigs were housed outdoors (Day *et al.* 2003). In Switzerland and Finland, tying stalls are still the predominant housing system for dairy cows (Busato *et al.* 2000, Roiha 2000). Tying stalls are more common in South Germany where smaller farms dominate (Hörning *et al.* 2004b).

Several methods of scoring systems are available to assess animal welfare at the farm level. One of these systems, the animal needs index (ANI 35) has got some importance in Austria. Organic farms must achieve a certain minimum level of points to be accepted for organic registration (Bartussek 2003). Roiha (2000) used the same system in 26 Finnish dairy farms. The ANI scores are primarily calculated on the animals' environment rather than on animal-based parameters; however, many scientists are now arguing for the inclusion of more animal-based parameters for on-farm assessment schemes (e.g. Hegelund *et al.* 2003, Winckler *et al.* 2003).

Investigations have shown that farmers do not always maintain suitable standards for housing animals (Hörning *et al.* 2004a,b). For example, in Germany, some farmers did not follow all the provisions of the German regulations for keeping laying hens. Therefore, it seems useful to train people in organic certifying organisations to be aware of the standards and to ensure they are followed.

The abovementioned regulations contain many discretionary provisions or derogations. It seems in some cases that exceptions are regarded as the rule. For example, in Germany, organic advisers generally say that an exercise yard for cattle is not necessary for loose housing systems in winter if the animals have access to pasture in summer. Other difficulties in interpretation might occur. A derogation of the EU regulation allows tying stalls for cattle in small herds after 2010. To enact this derogation therefore requires a definition of a 'small herd'. These ambiguities will increase the risk that some farmers will try to fulfil the necessary minimum, and for this reason will not fulfil the expectations of consumers. Consumers in most European countries attach great importance to animal welfare when buying organic products (Hamm and Gronefeld 2004, Anonymous 2005).

The EU regulation allows transition periods in some cases; for example, loose housing for cattle or access to the outside until 2010. Stanchion barns are still common on smaller farms. Reconstruction to loose housing is often connected with high investment costs. Therefore, many farmers seem to wait until the end of the derogation period. However, they will sell their products as organic in the meantime. Again, this may reduce consumers' confidence.

The fulfilment of regulations does not guarantee animal welfare *per se*. To reiterate, the regulations offer the precondition for welfare. Good welfare depends on many more factors that could be regulated for in them standards. Therefore, good management is essential to achieve good animal welfare and farmers need to be trained in appropriate management techniques to achieve this end. Scientifically sound methods are available to judge animal welfare at the farm level (e.g. Sorensen and Sandoe 2001, Webster and Main 2003).

Although farmers in some countries have difficulty converting their intensive housing systems, in other countries problems might occur with very extensive systems. For example, in extensive grazing systems such as those in Australia or Argentina, cattle or sheep may have problems with water availability or with protection against negative climatic influences (heat, wind) or even against predators.

Alternative housing systems are often relatively new and experience is thus limited. Housing systems are often not included in the normal education of farmers because they are regarded as too 'exotic'. Therefore, efforts should be made to close these knowledge gaps in practice.

Health risks

Conflicts may occur between animal welfare, health, productivity or environmental protection. The guidelines for organic livestock farming aim to offer animals the opportunity to fulfil their behaviour requirements. However, some alternative systems may impose additional health risks. Health problems such as mastitis in dairy cows, endoparasites and feather pecking are common on many organic farms (e.g. Thamsborg *et al.* 2004). For example, organic bedding materials may favour the growth of mastitis bacteria. Access to organic materials like bedding in the sleeping area or on the earth in outside areas may favour endoparasitic infection of many species. Housing of poultry in large groups may enhance the risk of feather pecking. The solution may not be to eliminate these risk factors because of the risk that behavioural problems will occur, but to reduce the risks with appropriate measures like good quality bedding, pasture changes or recreation possibilities. For example, Bestman and Wagenaar (2003) found that on Dutch organic farms the presence of cocks and rearing of pullets at the farm in outdoor runs reduced the risk of feather pecking in layers. Herd management and human–animal relationships are important influences in reducing the risk of injuries in loose housing of horned dairy cows (Menke *et al.* 1999).

Environmental pollution

Housing systems for farm animals could lead to environmental pollution via gases, dust and odours. All intensive housing systems produce slurry or liquid manure. Many straw-based systems comprise production of solid manure. Emissions could occur from the stable through dung storage and dung spreading. Straw-based systems result in higher dust concentrations in the stable and therefore in higher emission rates. However, odour emissions are higher in slurry systems. Ammonia (NH_3) emissions are higher from solid manure storage, presuming that storage facilities for liquid manure are covered. If slurry is not introduced directly into the soil, ammonia emissions will be higher when spreading slurry than solid manure. Methane emissions are also higher in slurry-based systems. However, nitrous oxide emissions seem to be higher from solid manure systems (i.e. deep litter, straw yard) (e.g. Kuczynski *et al.* 2005).

Additional ammonia emissions can come from covered yards. Covered yards are additional emitting areas for ammonia emissions. Furthermore, increased pen or outside yard areas will increase emissions. Again, instead of reverting to conventional housing systems, the solution could be to decrease potential emissions within the given system (e.g. via cold temperatures, increasing the frequency of cleaning).

Profitability

In many cases, welfare-friendly systems mean higher investment or labour costs. The conversion of intensive to welfare-appropriate housing is often connected with high investment costs (e.g. conversion from stanchion barns to loose housing systems for cattle). However, within a given space, appropriate systems could be less expensive than intensive systems (no slurry channels, less technical facilities, no insulation). However, space per animal in appropriate systems is greater than in intensive systems, so this advantage could be counteracted. On the other hand, energy costs could be lower (reduced heating and/or ventilation in non-insulated, straw-based systems), although straw-based systems are connected with a higher labour requirement than systems without straw because of straw harvesting, transport, and rebedding. Exercise yard cleaning also means additional labour requirements. The higher investment or labour costs could be balanced by lower energy costs, better health and performance. However, in many cases, the productivity of organic livestock production systems is often lower than conventional systems because, for example, of the lower stocking rate with regard to arable land (e.g. Nicholas *et al.* 2004). Therefore, higher prices or subsidies will be necessary to keep profitability at an acceptable level.

Breeding

Breeding includes the choice of suitable performance parameters (breeding goals/traits), ways to combine performance information (e.g. selection index), selection of animals to reach breeding goals and the respective breeding techniques (e.g. natural mating, artificial insemination [AI]).

There is little literature is available concerning organic animal breeding. However, some of the issues associated with breeding were addressed in a NAHWOA workshop (Hovi and Baars 2001), and Boelling *et al.* (2003) and Pryce *et al.* (2004) have presented overviews about the subject. A network on organic animal breeding, Gesellschaft für Ökologische Tierhaltung (Society for Ecological Animal Husbandry), was founded in Germany in 2003, resulting in three workshops for cattle, pig and poultry research (http://www.zs-l.de). Nauta *et al.* (2003) published the results of a discussion on organic animal breeding in the Netherlands. According to these authors, most ideas about alternative breeding methods were developed for dairy cows. Conventional animal breeding has been well researched and some of the knowledge gained from this work can have application in organic agriculture.

IFOAM standards and EU regulations stress the importance of maintaining and conserving genetic diversity. According to these guidelines, preference should be given to indigenous breeds and strains as they are well adapted to local conditions. According to IFOAM standards, breeds should have good resistance to disease. The EU regulation regarding disease resistance is more specific: 'Selection should avoid specific diseases or health problems with some breeds or strains used in intensive agriculture' (EUR-Lex 1999), including issues such as pale, soft, exudative (PSE) meat in pigs, sudden death, difficult births.

Another point connected with breeding is the origin of animals. According to organic standards, livestock obtained from off the farm should be from organic farms. This can be difficult as many breeding companies or hatcheries work conventionally. However, some animals may come from conventional farms to enlarge the genetic pool. The EU regulation says: 'For supplementing natural growth and renewal of the herds, a maximum of female nulliparous animals of 10% of equine and bovine species and of 20% of adult porcine, ovine and caprine species per year is allowed (up to 40% when a major extension is undertaken or a breed changed or endangered)' (EUR-Lex 1999). In practice, mostly male breeding animals are bought from conventional farms in the case of ruminants or pigs, and females are mainly reproduced at the farm.

Problems with conventional breeds

High yielding breeds are selected for specialised performance (e.g. milk, growth rate, meat quantity, eggs). Such unidirectional high performance could stress the organism, for example through metabolic stress (Olesen *et al.* 2000). High-yielding animals are often very sensitive to management changes or mistakes. Performance-related health problems are common; examples include leg problems and metabolic disorders in meat poultry and fattening pigs, mastitis in dairy cows or diseases of the reproductive organs in laying hens and breeding sows (e.g. Hörning 1997 2000, Rauw *et al.* 1998, Postler 2002). Furthermore, high performances can only be realised with a high amount of concentrates. With regard to the world hunger problem, organic farming should aim to reduce feeding farm animals with concentrates because of a competition with human food.

An aim of organic agriculture is to keep breeds that are less vulnerable to diseases or management mistakes. This may result in a trade-off between 'hardiness' and productivity. Another possibility is not to exploit the full genetic potential of a high-yielding breed by feeding a feed ration with a lower nutrient content. However, this is not advisable for all classes of animals. It may work with dairy cows or fattening pigs. For example, Holstein Friesians normally are fed fewer concentrates in organic agriculture. Some health problems may arise, mainly with modern poultry hybrid lines (both meat and layer strains), when they are not fed to their genetic requirements. For example, poultry may still feel hungry and develop behavioural problems (e.g. feather pecking).

Genetic diversity

Intensive animal production with the selection for maximum unidirectional performance has led to a significant decrease in genetic diversity. About 30% of all domestic breeds are considered to be at critical levels, or are at least endangered. About 300 breeds have become extinct worldwide during the last 15 years (Scherf 2000). In Europe, half of the breeds present at the beginning of the 20th century have become extinct (Dohner 2002). Moreover, biodiversity has decreased within breeds resulting in increased genetic uniformity; this has been enhanced by the practices of multinational breeding companies. Some Holstein bulls, for example, have more than one million descendants. Genetic erosion is especially acute for poultry, pigs and high-yielding dairy breeds like Holsteins. A higher diversity can still be found in sheep and goats.

One of the advantages of using local breeds is that they are usually very well adapted to regional conditions. They are often better suited than modern breeds especially under harsh conditions. This could be also true for regions where particular breeds are not native (e.g. Brahman cattle in Australia). Local breeds can have some unknown properties or traits that will be important. They often have properties like disease resistance or longevity that are important for sustainable agriculture systems. Furthermore, rare breeds are part of the cultural history of the country of origin.

In reality, the same breeds are commonly used in organic and conventional agriculture. For example, only 10% of rare breeds are used in German organic dairy farms (Hörning *et al.* 2004b). This rate has not changed in the last 10 years. Most German or Dutch farmers and organic advisers prefer modern breeds because of higher performances (Nauta *et al.* 2003, Hörning *et al.* 2004a).

Lower performances could be partially outweighed by better health or longevity. Other compensation possibilities include higher product prices or subsidies. In many European countries, governments pay subsidies for keeping endangered breeds. However, in many cases these subsidies are not high enough to completely compensate for lower production. It could be useful, therefore, to use the preservation of an old breed as a marketing tool to convince consumers to pay higher prices. One positive example could be the Swabian-Hall saddleback pig in Germany. The meat is marketed successfully via a marketing company as a premium product, highlighting the good quality of the meat and the local origin (www.besh.de). As a compromise, the sows are normally bred with Pietrain boars to achieve a higher muscle amount. The company uses the special marketing brand assigned by the EU 'controlled origin'. This approach was very successful. Within 15 years, the population increased considerably and is no longer considered to be at acute risk of extinction.

The FAO has developed many activities in the field of livestock genetic diversity conservation (e.g. (http://www.fao.org/biodiversity/Domestic_en.asp). The FAO set up a Commission on Genetic Resources for Food and Agriculture (CGRFA), which is the major international forum for developing policies on genetic resources. CGRFA started a global strategy for the management of farm animal genetic resources in 1992. The goal of the strategy is to overcome genetic erosion of animal resources, and to ensure use of these resources. The strategy provides a framework for assisting countries, regions or other stakeholders in installing management programs (Scherf 2000). In order to implement the global strategy, FAO developed a communication and information tool, the Domestic Animal Diversity Information System (DAD-IS). In addition FAO established a global databank for farm animal genetic resources. In this databank, data from 189 countries are collected. Currently 6379 breeds from 30 mammalian and avian species are included, from 140 countries (in 1995 there were only 3882 breeds). These data were used as a basis for the publication of the world watch list for domestic animal diversity (Scherf 2000). FAO is planning to publish a report on the state of the world's animal genetic resources in 2006. The inventory compiled by Porter (2002) of endangered livestock breeds contains about 9000 entries of breeds, types and varieties, and also of extinct ones. Dohner (2002) described more than 180 endangered British and North American breeds. Hall (2005) provided detailed information regarding livestock biodiversity and gave recommendations for preservation.

In many countries, organisations are working for the conservation of endangered livestock breeds (e.g. the supranational working Rare Breeds International (www.rbi.it), Rare Breeds Survival Trust in the UK (www.rare-breeds.com), Stichting Zeldzame Huisdierrassen in the Netherlands (www.szh.nl), Pro Specie Rara in Switzerland (www.psrara.org), Gesellschaft zur Erhaltung alter und gefährdeter Haustierrassen in Germany (www.g-e-h.de), Rare Breeds Canada (www.rarebreedscanada.ca), the American Livestock Breeds Conservancy in the USA (www.albc-usa.org), Rare Breeds Conservation Society of New Zealand (www.rarebreeds.co.nz), Rare Breeds Trust of Australia (www.rbta.org). These organisations normally provide information about the history of old breeds and their status, and offer links to breed associations.

Breeding objectives

Breeding objectives (traits) appropriate for organic husbandry are the focus of much discussion. Some organic dairy farmers have little awareness of modern breeding techniques and strong trust in the practices of commercial breeding companies (Nauta *et al*. 2003). Breeding objectives will not be the same for all conditions because of the huge variation in conditions. In some cases, existing objectives will get another weighting within the selection index for organic breeding purposes. In other cases, new objectives will be added. General breeding objectives for all farm animal species in organic agriculture are longevity, vitality and fertility. In recent years, breeding for disease resistance has been the subject of much research attention, mainly in cattle and sheep (e.g. Axford *et al*. 2000). The Scandinavian health recording system for dairy cattle could be identified as a good example of a health recording system. Veterinarians within that scheme collect data about veterinary treatments. In other countries, parameters like somatic cell counts as an indicator for mastitis are provided regularly during milk recording. A potential disadvantage of this approach is the need for thorough performance recording schemes.

Table 6.4 shows further examples of suitable breeding traits for organic livestock. In general, these traits lead away from maximum performance. Instead, an optimum performance should be the aim.

Table 6.4 Aims and possible breeding traits for organic livestock breeding

Aims	Breeding traits (examples)
Maintenance of biological diversity	Conservation measures for endangered breeds
Lowering of environmental pollution	Improved nutrient efficiency
Longevity	Lifetime production (milk, piglets, eggs)
Health	Disease resistance, increase of robustness
Adaptation to alternative housing systems	Pigs: good mothering ability, suitability for outdoor production; laying hens: low rate of feather pecking
Reduced amount of concentrates	Good roughage conversion
Food quality	Meat quality in pigs or poultry

Alternative breeding approaches

Dairy cows

Selection indexes are used in most breeding programs. Different production traits are multiplied with economic factors and these partial indexes are added up to an overall value. Also, in several conventional breeding schemes for dairy cows, functional traits like health, fertility or longevity have gained more importance over the last few years despite their low heritability. One suitable method for organic selection indexes would be to put another weight on some of these traits so that the ranking of available sire animals will change. Normally, functional traits like longevity or health will get a higher priority and performance traits a lower priority. For example, better persistence of milk performance within lactation may be an aim (flatter lactation curve), and also a lower milk production in the first lactation (e.g. Essl 1998). Both traits are often not considered in conventional breeding programs.

Ecological breeding indexes could be good an alternative until specific animals bred for organic agriculture are available. There are some examples where such technology (e.g. ecological total breeding value, ecological index) has been used (e.g. Bapst 2001; Baumung *et al.* 2001; Postler 2002). For example, twice a year a list is published in Germany with a ranking of breeding bulls from different breeds. In Switzerland, catalogues of conventional breeding companies also contain ecological indexes. The disadvantage is that only those traits could be used for which data are collected. For other potentially useful traits for organic agriculture, no information is yet available (e.g. conversion ability of roughage). Furthermore, bulls that are ranked highly were usually bred for high unidirectional performances.

Professor Bakels in Munich, Germany, developed breeding for lifetime performance as a concept. The idea is that a dairy cow, which realised a high lifetime milk performance, must also be healthy and fertile. Within a breed, families with very high lifetime performances are identified and bred, using rotational breeding and also slight inbreeding. Economic advantages of a high lifetime performance are that rearing costs are spread over more cows, and that selection possibilities are higher because more descendants are available. However, only conventionally reared, AI bulls are used, often from North American origin. There are farmer groups in Germany, the Netherlands, Switzerland and Austria working with lifetime performance (Günter Postler, pers. comm. 2005). They publish yearly catalogues with recommended bulls from which 90% are bred specially for lifetime production or organic farming. The idea of lifetime production could also be transferred to sows and laying hens (number of piglets or respective eggs per lifetime).

In the Netherlands, the concept of family breeding was developed by the farmer Dirk Endendijk. He successfully bred cows that produced more than 10,000 kg per lactation using the original Dutch Friesian cattle (Endendijk *et al.* 2001). Mainly animals present at a given farm are used for breeding within that system. Another typical feature is the use of several bulls at a time for natural mating. Like the concept of lifetime performance, cow families with a high lifetime production are used, again also utilising some inbreeding.

Crossbreeding is used in some countries for dairy cows, such as Holstein Friesian × Jerseys in New Zealand. In the tropics, cross breeding is common, normally combining the advantages of local and high-yielding European breeds. In doing so, heterosis effects could be used (higher performance in offspring than in the parental generation). Examples include improvements in milk production, parasite and disease resistance, adaptation to climate, or progeny survival rates. However, the use of crossbreeding requires higher inputs (e.g. one part of the herd must be kept pure bred). Another question is what to do with the F1 animals (first generation of crossbreeding). The F1 generation can be either produced continuously or a rotational crossbreeding is possible.

Pigs

Alternative breeding approaches are much less common in pigs and poultry than in dairy cows. There is a large variation in the (relatively small) organic pig market, ranging from normal lean meat for supermarket chains up to relatively fat breeds for sausage production. Therefore, it is difficult to define appropriate breeding goals for all possible organic marketing purposes. In countries like Germany and Austria, only the amount of lean meat is paid for at conventional slaughterhouses. In other countries like Denmark or Switzerland, intramuscular fat percentage (IMF) is also considered. IMF is important for meat quality as it is highly correlated to sensory properties like taste, tenderness and juiciness. Breeding for highly muscular animals has led to a decrease of IMF and an increase of PSE meat in pigs (e.g. Hörning 1997). Another parameter is fat quality, which is important, for example, for sausage production. However, many organic consumers also ask for lean meat. Therefore, a conflict of goals exists and it will be necessary to convince those consumers of the advantages of meat with a higher IMF.

Some breeding companies are looking for traits like fertility or lifetime performance in mother breeds. Alternatively, conformation parameters can be considered, such as limb posture as an indicator for lameness susceptibility. Furthermore, behavioural traits like mothering ability or suitability for group housing are considered by some companies. For example, Grandinson *et al.* (2003) found a relationship between sows' avoidance of the farmer and piglet mortality. This is especially important in the loose housing of farrowing sows favoured in organic agriculture. Similar to cow breeding, suitable measuring methods are missing for some parameters, such as roughage conversion. There are examples of breeds suited especially for specific housing conditions, like some breeds developed for outdoor pig production in the UK.

Poultry

Development of hybrid breeding has led to strictly separate strains of poultry for meat or egg production. Selection for very high performances has promoted many health problems, such as sudden death syndrome, leg problems or ascites in broilers. At least for meat poultry, the EU regulation for organic agriculture takes this into account, because minimum slaughter ages are prescribed, which are much longer than for conventional production.

Male layer chickens are normally killed directly after hatching because fattening them is not economical. This is a serious ethical problem. Furthermore, conventional laying hens are normally used only for one laying period (about one year). Again, this could be considered as ethically questionable. It is very difficult to feed high-yielding poultry strains according to their nutritional requirements with the feedstuffs allowed for organic agriculture. Supplying poultry with essential amino acids is particularly difficult with the available protein feedstuffs.

Performances should be reduced for organic farming because of the abovementioned reasons. Vitality and adaptability will be especially important for birds in alternative housing systems because modern layers have been selected under cage conditions. Feather pecking and cannibalism can be a problem for many hybrid strains under alternative housing conditions. However, there is some heritability and therefore selection against these behavioural disturbances might be useful (Sorensen 2001).

Most organic poultry farmers use normal hybrid strains at least for laying hens. For meat poultry like turkeys or broilers some slower growing strains are available, bred for example, for the free-range label production in France. However, these birds are also hybrids, which mean that the farmers cannot reproduce their own animals.

Tests in Germany and in Denmark have shown that the egg production of purebred layers is much lower than those of modern hybrid strains (Hörning 2000, Sorensen 2001). During the last 30 years these purebred strains have been selected only for appearance. Therefore, at the moment, no optimum breed for organic agriculture seems to be available. The production rate of purebreds is too low, and modern hybrids have a tendency for feather pecking and cannibalism. In the long run, the development of a dual-purpose breed (meat and eggs) could be the solution for organic farming. Both meat and egg performance will be lower than of modern hybrid strains, however. Therefore, consumers must be convinced to buy these more expensive products. Prices for organic eggs or meat are relatively high. Furthermore, the efforts of organic farmers or associations will be necessary. The big breeding companies will not develop an organic breed in the short term because the organic market is too small for them.

Genotype × environment interactions (G × E) pose an additional challenge to using performance information. Generally, G × E interactions mean that animals of the same origin might give different performances in different environments. The G × E interactions are more important in very different environments; therefore, the performance of animals in vastly different environments can be difficult to compare. For example, Sorensen (2001) has shown that a purebred laying hen (Danish Skalborg) had a similar performance in both cage and alternative housing systems. However, the compared hybrids had a lower production in alternative than in cage systems. Similarly, a local breed (Sonali) showed a better performance than Lohmann Brown hens under semi-scavenging conditions in Bangladesh (Sorensen 2001). Up to now, no information is available for G × E interactions that compare conventional and organic agriculture (Boelling *et al.* 2003). One important precondition to estimating G × E interactions is that a great deal of data is necessary.

Another problem is that testing facilities normally work conventionally at least with pigs or poultry. For example, in intensive feeding and housing systems, only concentrates are used, which is not allowed in organic agriculture. In addition, results obtained under such conditions might not be transferable to organic conditions.

Breeding practices

According to IFOAM standards and EU regulations, breeding practices should respect the animals' natural behaviour. Therefore, natural mating is preferred. Methods that depend on complex technologies should be avoided. Embryo transfer and cloning are prohibited. Hormones to induce ovulation and birth are prohibited unless for medical reasons, although AI is permitted.

Invasive techniques like AI or embryo transfer do not respect the natural behaviour of an animal species, and farmers may become more dependent on breeding companies. Furthermore, the genetic basis of a breed will be reduced with these techniques because fewer breeding animals are used. Organic livestock husbandry aims for natural breeding methods. However, AI is still common with some species. In Germany for example, most organic dairy farmers are still using AI,whereas beef farmers mainly use natural mating (Hörning *et al.* 2004b).

Embryo transfer (ET) is prohibited in organic farming. However breeding bulls used for AI are often produced via ET. Furthermore, criteria should be set up for bulls for natural mating in many countries. Other options to encourage the use of natural mating are rotation of breeding animals with other farms, or some farmers could be paid for keeping male breeding animals. Natural breeding normally results in a higher breeding success because the sire is better able to detect oestrous females. However, if the sire inherits health problems that only become apparent later on, many descendants will be affected.

Another question is whether quantitative trait loci (QTL) methods should be used in organic agriculture (Pryce *et al.* 2004). In identifying the genes responsible for certain breeding traits, gains can be increased. These molecular techniques are becoming increasingly common in conventional breeding; for example, testing for the malignant hyperthermia syndrome

(MHS) gene in pigs to reduce stress susceptibility. However, these tests use genetic engineering methods which are questionable for organic agriculture because the use of genetic modified organisms is not allowed.

Conclusions

The availability of scientific literature specific to organic livestock husbandry is limited. Standards on organic animal housing should be more precisely defined in some cases and should be controlled by well-trained people. However, keeping high standards is not enough to guarantee animal welfare. Management is very important in that context. Education of farmers, consultants and veterinarians about organic livestock husbandry should be extended.

Alternative housing systems often mean higher costs (e.g. more space and labour). Therefore, farmers must either get higher prices or subsidies. Some alternative systems could lead to specific risks for animal health or the environment. Measures to reduce these risks should be investigated further without taking away the advantages for the animal's natural behaviour.

Organic livestock systems are very heterogeneous. Therefore, it is not easy to define breeding goals (traits) for all purposes. Food quality, adaptability, longevity, disease resistance or roughage conversion can be listed as traits suitable for organic or sustainable animal agriculture. One aim of organic agriculture is the maintenance of genetic diversity. Endangered old breeds of domestic livestock often have the desired properties (e.g. adaptability, vitality), which makes them well suited for organic agriculture. However, lower performances mean a lower profitability. Therefore, farmers again must aim for higher prices or subsidies.

References

Anonymous 2005. *Attitudes of Consumers Towards the Welfare of Farmed Animals*. Special Eurobarometer No. 229, European Commission, Bruxelles.

Axford, R.F.E., Bishop, S.C., Nicholas, F.W. and Owen, J.B. (eds) 2000. *Breeding for Disease Resistance in Farm Animals*. CABI, Wallingford.

Bapst, B. 2001. Swiss experiences on practical cattle breeding strategies for organic dairy herds. In: Hovi, M. and Baars, T. (eds) *Breeding and Feeding for Animal Health and Welfare in Organic Livestock Systems. Proceedings of the 4th NAHWOA (Network for Animal Health and Welfare in Organic Agriculture) Workshop*. 24–27 March 2001. Wageningen, the Netherlands. pp. 44–50.

Bartussek, H. 2003. An historical account of the development of the animal needs index ANI-35L as part of the attempt to promote and regulate farm animal welfare in Austria – an example of the interaction between animal welfare science and society. *Acta Agriculturae Scandinavica, Section A, Animal Science*. Suppl. 30: 34–41.

Baumgartner, J., Leeb, T., Gruber, T. and Tiefenbacher, R. 2003. Husbandry and animal health on organic pig farms in Austria. *Animal Welfare* 12: 631–636.

Baumung, R., Sölkner, J., Gierzinger, E. and Willam, A. 2001. Ecological total merit index for an Austrian dual purpose cattle breed. In: Hovi, M. and Baars, T. (eds) *Breeding and Feeding for Animal Health and Welfare in Organic Livestock Systems. 4th NAHWOA (Network for Animal Health and Welfare in Organic Agriculture) Workshop*. 24–27 March 2001. Wageningen, the Netherlands. pp. 14–34.

Bestman, M.W.P. and Wagenaar, J.P. 2003. Farm level factors associated with feather pecking in organic laying hens. *Livestock Production Science* 80: 133–144.

Boelling, D., Groen, A.F., Sorensen, P., Madsen P. and Jensen, J. 2003. Genetic improvement of livestock for organic farming systems. *Livestock Production Science* 80: 79–88.

Busato, A., Trachsel, P. and Blum, J.W. 2000. Frequency of traumatic cow injuries in relation to housing systems in Swiss organic dairy farms. *Journal of Veterinary Medicine, Series A* 47: 221–229.

Day, J.E.L., Kelly, H., Martin, A. and Edwards, S.A. 2003. Towards a baseline assessment of organic pig welfare. *Animal Welfare* 12: 637–642.

Dohner, J.V. 2002. *The Encyclopedia of Historic and Endangered Livestock and Poultry Breeds*. Yale University Press, New Haven.

Endendijk, D., Baars, T. and Endendijk, H. 2001. Family breeding at Rivelinohoeve. In: Hovi, M. and Baars, T. (eds) *Breeding and Feeding for Animal Health and Welfare in Organic Livestock Systems. Proceedings of the 4th NAHWOA (Network for Animal Health and Welfare in Organic Agriculture) Workshop*. 24–27 March 2001. Wageningen, the Netherlands, pp. 35–43.

Essl, A. 1998. Longevity in dairy cattle breeding – a review. *Livestock Production Science* 57: 79–89.

EUR-Lex 1999. *Council Regulation (EC) No 1804/1999 of 19 July 1999*. <http://europa.eu.int/eur-lex/pri/en/oj/dat/1999/l_222/l_22219990824en00010028.pdf>. Office for Official Publications of the European Communities, Luxembourg.

EUR-Lex 2003. *Commission Regulation (EC) No 2277/2003 of 22 December 2003*. <http://europa.eu.int/eur-lex/pri/en/oj/dat/1999/l_222/l_22219990824en00010028.pdf>. Office for Official Publications of the European Communities, Luxembourg.

Fölsch, D.W. and Hörning, B. 1996. The importance of ethology to organic farming. In: Ostergaard, T.V. (ed.) *Proceedings of the 11th IFOAM International Scientific Conference. Vol. 1: Fundamentals of Organic Agriculture*. IFOAM, Tholey-Theley, Germany. pp. 125–138.

Foster, C. and Lampkin, N. 2000. *Organic and In-conversion Land Area, Holdings, Livestock and Crop Production in Europe*. RTD Programmme, Project FAIR3-CT96-1794, Final Report.

Goessler, R. (ed.) 2004. *Ökomarkt Jahrbuch 2004 – Verkaufspreise im ökologischen Landbau*. ZMP, Bonn.

Grandinson, K., Rydhmer, L., Strandberg, E. and Thodberg, K. 2003. Genetic analysis of on-farm tests of maternal behaviour in sows. *Livestock Production Science* 83: 141–151.

Hall, S.J.G. 2005. *Livestock Biodiversity: Genetic Resources for the Farming of the Future*. Blackwell Publishers, Oxford.

Hamm, U. and Gronefeld, F. 2004. *The European Market for Organic Food – Revised and Updated Analysis*. Organic Marketing Initiatives and Rural Development, School of Management and Business, Aberystwyth.

Hegelund, L., Sorensen, J.T. and Johansen, N.F. 2003. Development of a welfare assessment system for use in commercial organic egg production. *Animal Welfare* 12: 649–653.

Hermansen, J.E. 2003. Organic livestock production systems and appropriate development in relation to public expectations. *Livestock Production Science* 80: 3–15.

Hermansen, J.E., Lund, V. and Thuen, E. (eds) 2000. *Ecological Animal Husbandry in the Nordic Countries*. Danish Research Centre Organic Farming, Foulum, Tjele.

Hörning, B. 1997. Alternative Schweinezüchtung. In: GEH and B. Hörning (eds.) *Gefährdete Schweinerassen und Alternative Schweinezüchtung*. Gesellschaft zur Erhaltung alter und gefährdeter Haustierrassen, Witzenhausen. pp. 69–108.

Hörning, B. 1998. [Animal health and welfare on organic farms]. *Deutsche Tierärztliche Wochenschrift* 108: 313–321.

Hörning, B. 2000. Probleme der heutigen Geflügelzüchtung und mögliche Alternativen. In: GEH (ed.) *Gefährdete Geflügelrassen und Alternative Geflügelzüchtung*. Gesellschaft zur Erhaltung alter und gefährdeter Haustierrassen, Witzenhausen. pp. 52–71.

Hörning, B., Simantke, C., Aubel, E. and Andersson, R. 2004b. *Ökologische Milch- und Rindfleischproduktion: Struktur, Entwicklung, Probleme, politischer Handlungsbedarf*. Schlussbericht des Forschungsprojekts im Auftrag der Geschäftsstelle Bundesprogramm Ökologischer Landbau in der Bundesanstalt für Landwirtschaft und Ernährung, Projektnummer 514-020E348. Bundesanstalt für Landwirtschaft und Ernährung, Bonn.

Hörning, B., Trei, G. and Simantke, C. 2004a. *Ökologische Geflügelproduktion: Struktur, Entwicklung, Probleme, politischer Handlungsbedarf*. Schlussbericht des Forschungsprojekts im Auftrag der Geschäftsstelle Bundesprogramm Ökologischer Landbau in der Bundesanstalt für Landwirtschaft und Ernährung, Projektnummer 514-020E343. Bundesanstalt für Landwirtschaft und Ernährung, Bonn.

Hovi, M. and Baars, T. (eds) 2001. *Breeding and Feeding for Animal Health and Welfare in Organic Livestock Systems. NAHWOA (Network for Animal Health and Welfare in Organic Agriculture) Workshop*. 24–27 March 2001. Wageningen, the Netherlands.

IFOAM 2002. *Final Draft 2002. Basic Standards for Organic Production and Processing*. International Federation of Organic Agriculture Movements, Tholey-Theley, Germany.

Joint FAO–WHO Food Standards Programme 1999. *Codex Alimentarius: Guidelines for the Production, Processing Labelling and Marketing of Organically Produced Food*. Joint FAO-WHO Food Standards Programme, Rome.

Kuczynski, T., Dammgen, U., Webb, J. and Myczko, A. 2005. *Emissions from European Agriculture*. Wageningen Academic Publishers, Wageningen.

Kyriazakis, I. and G. Zervas (eds) 2002. Organic meat and milk from ruminants. In: *Proceedings of the International Conference of the Hellenic Society of Animal Production and the British Society for Animal Scienc*e. *4.–6.10.01, Athens, Greece*. Wageningen Academic Publishers, Wageningen.

Lund, V. and Algers, B. 2003. Research on animal health and welfare in organic farming – a literature review. *Livestock Production Science* 80: 55–68.

Menke, C., Waiblinger, S., Fölsch, D.W. and Wiepkema, P.R. 1999. Social behaviour and injuries of horned cows in loose housing systems. *Animal Welfare* 8: 243–258.

Nauta, W.J., Groen,A.F., Baars, T., Roep, D. and Veerkamp, R.F. 2003. *A Vision on Organic Animal Breeding*. Louis Bolk Institute, Driebergen.

Nicholas, P.K., Padel, S., Cuttle, S.P., Fowler, S.M., Hovi, M., Lampkin, N.H. and Weller, R.F. 2004. Organic dairy production – a review. *Biological Agriculture and Horticulture* 22: 217–249.

Olesen, I., Groen, A.F. and Gjerde, B. 2000. Definition of animal breeding goals for sustainable production systems. *Journal of Animal Science* 78: 570–582.

Pathak, P.K., Chander, M. and Biswas, A.K. 2003. Organic meat – an overview. *Asian Australasian Journal of Animal Science* 16: 1230–1237.

Porter, V. 2002. *Mason's World dictionary of Livestock Breeds, Types and Varieties*. CABI, Wallingford.

Postler, G. 2002. Naturgemäße Rinderzucht – ganzheitliche Betrachtungsweisen in der naturgemäßen Viehwirtschaft. G. Postler, Glonn.

Pryce, J.E., Conington, J., Sorensen, P., Kelly, H.R.C. and Rydhmer, L. 2004. Breeding strategies for organic livestock. In: Vaarst, M., Roderick, S., Lund, V. and Lockeretz, W. (eds) *Animal Health and Welfare in Organic Agriculture*. CABI, Wallingford. pp. 357–388.

Rauw, W.M., Kanis, E., Noorhuizen-Stassen, E.N. and Grommers, F.J. 1998. Undesirable side effects of selection for high production efficiency in farm animals – a review. *Livestock Production Science* 56: 15–33.

Roiha, U. 2000. Evaluation of animal welfare on organic dairy farms in Finland. In: Hermansen, J.E., Lund, V. and Thuen, E. (eds) *Ecological Animal Husbandry in the Nordic Countries*.

Proceedings of the NJF-Seminar (16–17.9.99, Horsens, Denmark). Danish Research Centre Organic Farming, Foulum, Tjele. pp. 187–196.

Scherf, B.D. (ed.) 2000. *World Watch List for Domestic Animal Diversity*. FAO, Rome.

Sorensen, P. 2001. Breeding strategies in poultry for genetic adaptation to the organic environment. In: Hovi, M. and Baars, T. (eds.) *Breeding and feeding for animal health and welfare in organic livestock systems. Proceedings of the 4th NAHWOA (Network for Animal Health and Welfare in Organic Agriculture) Workshop*. 24–27 March 2001. Wageningen, the Netherlands. pp. 51–61.

Sorensen, J.T. and Sandoe, P. (eds) 2001. Assessment of animal welfare at farm or group level. *Proceedings of the International Workshop. Acta Agriculturae Scandinavica, Section A, Animal Science*. Suppl. No. 30: 429–708.

Thamsborg, S.M., Albihn, A., Pedersen, M.A. and Christensen, B. (eds) 2000. Veterinary challenges in organic farming. *Proceedings of the 14th Internordic Symposium of NKVet (Hveragerdi, Iceland, 5.-8.10.00)*. *Acta Veterinaria Scandinavica Supplementum* 95.

Thamsborg, S.M., Roderick, S. and Sundrum, A. 2004. Animal health and diseases in organic farming – an overview. In: Vaarst, M., Roderick, S., Lund, V. and Lockeretz, W. (eds) *Animal Health and Welfare in Organic Agriculture*. CABI, Wallingford. pp. 227–252.

Vaarst, M., Roderick, S., Lund, V. and Lockeretz, W. (eds) 2004. *Animal Health and Welfare in Organic Agriculture*. CABI, Wallingford.

Vermeer, H.M., Altena, H., Bestman, M., Ellinger, L., Cranen, I. and Spoolder, H.A.M. 2000. Monitoring organic pig farms in the Netherlands. *Proceedings of the 51st Annual Meeting of the European Association for Animal Production*. European Association for Animal Production (EAAP), The Hague.

Webster, A.J.F. and Main, D.C.J. (eds) 2003. Proceedings of the 2nd International workshop on the assessment of animal welfare at farm or group level. *Animal Welfare* 12.

Willer, H. and Yussefi, M. (eds) 2004. *The World of Organic Agriculture – Statistics and Emerging Trends*. IFOAM, Bonn.

Winckler, C., Bühnemsann, A., Seidel, K., Küffmann, K. and Fenneker, A. 2001. Label pig production and organic pig farming – a pilot study on housing and welfare related parameters in sows. *Proceedings of the International Symposium 2nd Technical Section of CIGR, 23–25.10, Sklarska Poreba, Czech Republic*, pp. 479–490.

Winckler, C., Capdeville, J., Gebresenbet, G., Hörning, B., Roiha, U., Tosi, M. and Waiblinger, S. 2003. Selection of parameter for on-farm welfare assessment protocols in cattle and buffalo. *Animal Welfare* 12: 619–624.

Younie, D. and Wilkinson, J.M. (eds.) 2001. Organic livestock farming. *Proceedings Conf. Edinburgh, Reading, 9–10 February 2001.* Chalcombe, Lincoln.

Chapter 7

Animal health and nutrition in organic farming

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Introduction

Animals are important in organic farming systems, both as a part of the concept and in practice, where there is great weight on forming an integrated system with harmony between the land, the animals and the people, involving local recirculation of feed and manure. Good animal health and welfare is an important goal for organic husbandry. In contrast to crops, animals are not just parts of the farming system, they are also sentient creatures and as such they deserve special moral consideration. They are individuals that need to be cared for, they can suffer, and they can interact with each other and with the humans and environment around them. Animal management is, therefore, very different from crop management. Humans have a moral obligation to treat animals well and to intervene before they suffer or die, as this is unacceptable. Organic farming principles go much further than promoting animal welfare in terms of avoiding suffering. One of the basic principles of organic farming refers to access to 'natural' behaviour for organically managed animals, which substantially broadens the concept of 'welfare'. These perspectives are presented and discussed in *Chapter 8*, where Lund emphasises the importance of integrating naturalness into the concepts and practical application of animal welfare in organic animal husbandry.

The animal welfare goal of avoiding suffering allows the use of synthetic medicines for treating sick animals. This is the only circumstance in organic agriculture where use of 'chemicals' is allowed and even recommended in Europe. In the United States of America (USA), antimicrobial treatments are completely prohibited. Some farmers, therefore, change their disease treatment patterns and turn to so-called alternative or complementary methods, sometimes in combination with anti-inflammatory drugs ('pain-killers'). No matter how diseases are managed, the most sustainable way to avoid suffering and the need for disease treatment is to make more fundamental changes in husbandry methods, such as breeding for increased disease resistance and introducing more species-appropriate housing, and a well-balanced diet. Hörning (see *Chapter 6*) discusses aspects of breeding and housing, and we will discuss the aspects of feeding and disease management.

Organic farming in a global context is emphasised in this book, and therefore we touch on perspectives of non-certified organic farming, in the way it exists in many regions of the world.

In most countries, there are hardly any local markets for certified organic livestock products (e.g. in most African countries), and export is limited for all livestock products as a result of disease status. Certified organic products consist mainly of fruits and cereals for export to privileged consumers such as those in north-western Europe. The certification procedures are too costly for most farmers, especially when nobody wants to pay extra for organic products, organic producers lack support or premium prices are difficult to obtain. Parrott *et al.* (2005) discuss the issue of non-certified organic farming and categorise four main areas they call the 'hidden world of ecological farming':

1 explicit organic approaches (e.g. membership of certification agency);
2 like-minded approaches (e.g. permaculture movement in Zimbabwe);
3 low external input sustainable agriculture (weight on local resources and processes); and
4 traditional farming ('food grown without chemicals', or 'organic by default').

In this chapter, we will keep the basic ideas of organic animal husbandry in mind and also include the potential organic livestock production with examples from areas that are not certified. Organic farming can in this context be seen as not only a way of producing 'certified animal products' but also as a way of farming sustainably, emphasising a harmonious way of using land and keeping animals.

There is great diversity among countries and regions regarding different ways and conditions for farming; farms locations range from mountain to grassland areas, and farming systems from traditional to intensive systems. The aim of this chapter is to present and discuss aspects of animal health and feeding in organic farming systems. A short overview of current knowledge about animal health, welfare and disease in organic agriculture is presented. For nutrition especially, we will focus on the interactions between nutrition and animal health and welfare. We have chosen to concentrate mostly on dairy cattle and grassland feeding, but also provide other examples.

Organic livestock production and animal disease patterns – an overview

Organic livestock production and products on a global level

It is difficult to get an overview of the development and composition of organic livestock production at a global level. Not even in Europe, where organic farming is well established in many countries, do detailed official statistics exist regarding organic livestock farming. Organic farms and land being converted to organic farming was about 3.5% of the land in Europe in 2003, covering 5.8 million hectares on 155,100 farms in 25 countries in the European Union (EU). The area and number of farmers converting differs between countries. For example, during 2003, land used for organics increased in Germany, France, Portugal, Greece, Austria and Spain, but decreased in Denmark, the United Kingdom (UK) and the Netherlands.

The availability of organic livestock products on the market varies extremely on a global level. In the EU, the most important markets exist in Germany, France, the UK and Italy, as well as Denmark, Austria and Switzerland. Considerable variation exists among product categories. For crops, the average market share in the EU was between 1% and 1.8% in 2001, where the organic share of the total market for beef was 1.6% in 2003, 1.2% for milk and milk products, 1.3% for eggs, but 0.6% or less for pig and poultry meat (Hamm and Gronefeld 2004). It is difficult to establish a balance between supply and demand for the organic markets for milk, beef and sheep and goat meat. The pattern of organic products sold as conventional in 2001 differed considerably between countries. However, in the EU, an average of 32% of the milk, 31% of the beef and 46% of the sheep and goat meat had to be sold to conventional outlets often at a lower price than that received for organic produce (Hamm and Gronefeld 2004).

Animal disease patterns: an overview

Good animal health and welfare is an explicit goal of organic farming. The term 'health' is often used to indicate 'no diseases', but covers many other components (see *Chapter 8*). We focus here on the disease problems that organic livestock production faces. We will approach this issue by giving a short overview of research findings related to disease levels, mostly in Europe. Organic livestock production has developed and changed in several ways over the past few years (e.g. standards, attitudes, infrastructure), which should also be kept in mind when organic research results are evaluated.

At the end of the chapter, we focus on the human role in organic livestock production, and suggest how to incorporate the principles of health care in a more structured manner.

The background to changes in disease patterns associated with conversion to organic production mostly relate to different housing conditions, feeding and outdoor production, treatment criteria, or changes in farmers' attitudes and perceptions. All these changes can have both positive and negative effects on disease patterns, and since the conversion period may be characterised by changes and new ways of managing the herd, the conversion itself may have a negative impact on the disease situation in the herd. Lund and Algers (2005) cautiously concluded, based on a literature review of peer-reviewed journal articles on animal health and welfare aspects in organic farming, that apart from parasite-related diseases, health and welfare in organic herds in general are the same or better than in conventional herds. Regarding parasitic diseases, Thamsborg *et al.* (1999) concluded that good prospects are expected for acceptable parasite control for organic farming systems.

Prominent disease problems are similar for organic and conventional dairy herds: mastitis, lameness and metabolic disease in adult cattle and internal parasite infections in young animals. The extent of these problems seems to vary more among farms than between organic and conventional farming. Mastitis has been recognised as the main animal health problem in organic dairy herds. Disease incidence in general appears to be similar, and occasionally higher compared with conventional production (Thamsborg *et al.* 2004, based on several European studies from 1988 to 2000). Studies from Norway (Ebbesvik and Løes 1994, Hardeng and Edge 2001), Sweden and Denmark (Vaarst and Enevoldsen 1994) in the 1990s found a lower incidence of treated cases of clinical mastitis in organic than in conventional dairy herds. Hovi and Roderick (1999) found that 50% of surveyed organic herds in England and Wales had relatively high levels of dry period mastitis compared with conventional farms, which had almost none. The differences between these findings could be associated with the widespread use of antibiotics in dry cow therapy in conventional herds in the UK. Comparative data on lameness and claw lesions are not conclusive. Offerhaus *et al.* (1993) showed that lameness was more prevalent on conventional farms. Vaarst (1995) and Vaarst *et al.* (1998b) found no major differences between systems, whereas a more recent Danish survey showed a higher incidence of recorded claw and leg disorders in recently converted organic farms (Danish Cattle Advisory Board 1998). In addition, a considerably higher incidence of liver abscesses has been detected in Danish organic compared to conventional dairy cows, probably caused by rumen acidosis due to higher grain proportions of feed ration and more grazing (Jørgensen *et al.* 2005).

Gastrointestinal parasites and coccidia may cause problems in organic dairy herds especially among young calves, and lungworm disease can be a problem among dairy cows, particularly in newly converted herds where the animals have not been on pasture previously. Most of these diseases can be controlled by appropriate management routines (Svensson *et al.* 2000), but still, 45% of Danish organic dairy farms had to fall back on anthelmintic treatments during the 2002 grazing season (Weinreich *et al.* 2005).

On Swedish smallholder farms, the most important health problems in organic sheep production seem to be associated with feeding, endoparasites, haemonchosis, diarrhoea, high lamb mortality (3–36%) and lean ewes. These problems were registered as the most common health problems in 37 organic sheep flocks, although this is not markedly different from problems in conventional flocks (Lindqvist 2001). A survey of organic farmers in the UK identified lameness, mastitis, fly strike, fasciolosis and other helminthoses as the most prevalent health problems (Roderick and Hovi 1999). The restrictions or prohibition of chemotherapy and chemoprophylaxis mean reliance on management practices such as lower stocking densities and closed flocks. Internal parasites, particularly gastrointestinal nematodes, are potentially a serious threat to organic sheep and goat production (Keatinge 1996). Most organic sheep farmers have to rely on grazing management such as repeated moves to clean pastures and supplementary feeding (Thamsborg *et al.* 1999), and regular (or pre-emptive) use of anthelmintics is still part of the control strategy in several countries. For example, Lindqvist *et al.* (2001) in Sweden estimated that roughly 20% of organic farmers drench ewes around lambing to control *Haemonchus contortus*.

The use of vaccination remains an option for organic producers. Clostridial vaccination of sheep is common on many conventional sheep farms in the UK, and 44% of surveyed organic farmers were also reported to vaccinate on a routine basis (Roderick *et al.* 1996), with 10% of flocks also being vaccinated against pasteurellosis.

Organic pig production varies significantly within Europe. Hermansen *et al.* (2004) argued that it is far more difficult for farmers to change existing conventional production systems to organic systems for pigs and poultry compared to ruminant systems. Depending on the system, farrowing and suckling or even fattening take place outdoors while housing with small outside exercise areas are provided in other systems in colder climate countries such as Germany, Denmark and the Netherlands. The latter systems have greater space allowance per pig than conventional production. Available data on animal disease patterns in pigs are limited, but health and welfare problems appear to differ between organic and conventional production. External parasites were seen as the biggest problem, followed by infertility, whereas diarrhoea and respiratory diseases were considered minor problems in a UK study in late 1990s (Hovi and Roderick 1999). Small Nordic case studies have shown a low incidence of diarrhoea and respiratory disorders but an increased incidence of joint diseases compared with indoor herds (Lindsjö 1996, Olsson *et al.* 1996, Vaarst *et al.* 1998a, Kugelberg and Johansson 2001), as well as outdoors where a case study (four herds) showed that among outdoor sows, traumatic lameness, injuries and sunburn were the most common clinical finding. In several studies, endoparasites and ectoparasites have been found to be highly prevalent, probably related to outdoor access, a high level of insoluble fibre (roughage), low level of hygiene and use of permanent pastures. Some organic herds have experienced massive problems with milk spots in the liver following recent *Ascaris* infection, resulting in rejections at slaughter. The use of antibiotics was very low in the organic herds. It is evident from several Danish studies that piglet mortality is high in organic systems (Lauritsen *et al.* 2000), although not different from conventional outdoor systems.

In general, the disease problems in intensive organic egg layer flocks seem to be the same as in conventional flocks, but at times at a higher level. The Danish Poultry Council (2002) found a higher mortality during the laying period in organic flocks than in any other egg-producing flocks. Without doubt, some specific disease problems are associated with free-range production. Coccidiosis, helminth parasites, histomoniasis and ectoparasites occur more frequently in free-range flocks, and diseases carried by wild birds (e.g. pasteurellosis, salmonellosis, avian tuberculosis) are risks to free-ranging birds. A recent example of disease outbreaks involving migrating birds occurred in July 2005, with concern expressed regarding the free-range status of organic poultry flocks in Europe following the outbreaks of avian flu in Asia, Russia and Kazakhstan. Organic and other free-range systems present both positive and negative welfare consequences compared with caged and confined poultry. Kristensen (1998) demonstrated that the mortality of organic laying hens in Denmark is 15% to 20% (4–5% in conventional battery cages; 9–10% in free-range production according to unpublished data from the Danish Poultry Council 1997), where later (unpublished) studies show considerably lower mortality on organic farms. Lampkin (1997) identified coccidiosis, external parasites, feather pecking and cannibalism as significant potential problems in organic and other free-range systems, where beak trimming is not allowed and not regarded as a suitable way of managing the problem. These problems are confirmed in more recent European studies. Some degree of feather pecking may be a natural preening process, but under less optimal conditions it results in considerable health and welfare problems. Breed and poultry strain are also important in relation to these problems. Feeding roughage and offering the poultry good outdoor conditions (shelter, shade, possibilities for dust bathing and areas with vegetation) can significantly reduce problems of excessive feather pecking and cannibalism. Nutritional deficiencies (e.g. lack of essential amino acids), unsatisfactory housing conditions and overcrowding can increase the problem. Bestman (2000) showed that farmers' understanding of the requirements of the birds was essential, so that they could adjust the system to the poultry's natural behaviour in an appropriate way. Organic rearing is important for the production of poultry, which should live their adult life under organic conditions. This means that chickens are reared on the floor (Gunnarsson *et al.* 1999 2000), as cage-adapted birds may not adapt to the floor under organic conditions and may develop feather pecking. In production of broilers (table hens), coccidiosis and breast blister seem to be the major disease problems (Pedersen *et al.* 2003).

Animal nutrition and feeding: the challenges of organic farming

A healthy well-balanced feed ration is crucial for health and welfare in animal herds. Following the principles for organic livestock production about naturalness, supporting the species-specific characteristics of animals, and at the same time emphasising local production, minimal transport and outdoor life, present many challenges to create a well-balanced animal production system (Zollitch *et al.* 2004). As discussed by Hörning (see *Chapter 6*), certified organic herds mainly rely on breeds and breeding goals of conventional herds, which may create a potential conflict because:

1 The conventional breeding goals often aim at high production levels, which may compromise natural behaviour or other breeding goals or characteristics (e.g. strong legs).
2 Feeding animals in accordance with their natural need (e.g. supporting ruminating through feeding in ruminants), attempting to support a production level that is physiologically feasible and still allowing natural behaviour, growth, reproduction and longevity in the herd. But feeding animals with genetic potential for high production according to guidelines of organic farming may not meet the animals' nutritional requirements and in this way may compromise their welfare.

So, in summary, the challenge of feeding the animals organically is to reach a quantity and quality of organic feedstuffs that supports the animals' physiology and production. At the same time, the ways of feeding (e.g. accessibility causing minimum stress in the animals) are adjusted to the changing situations of the animals (e.g. from dry period to lactation), and giving them maximum freedom of choice is also crucial for their wellbeing and performance.

The animals' basic nutritional requirements must be met, with regard to the levels of minerals and vitamins, to ensure their health and welfare. In some countries, supplementation with vitamins, trace elements and minerals is not a routine practice, whether certified organic or not. Another aspect of the interaction between animal health and nutrition regarding worm control is feeding with bioactive forages, which, for example Hoste *et al*. (2004) and Thamsborg *et al* (2005) describe, based on an EU-funded project WORMCOPS.

Feeding with home-grown feed

A basic principle of organic agriculture is that the animal herd forms a part of the entire farming system, which means that the nutrient supply in organic herds should be based primarily on home-grown feed, limiting the amount of bought-in feed material. In many organic farms, the genetic potential for production is used to maintain a high production, similar to the level of conventional herds. This puts some very high demands on the quality of feed as well as the amount of food intake. The aim of giving organic animals only home-grown feeds must be met in a manner that allows the animals' requirements to be met and still maintain ecological and economical sustainability. The way of fulfilling such an aim will depend on local and regional conditions and how the harmony between the animal herd and the land area can be supported. In the case of organic dairy farming, grassland feeding will be dominant (e.g. in Switzerland); hay feeding during winter can cover more than 90% of the nutrient requirement of the dairy cows (Früh 2004). An example from Australia with beef cattle is given, based on pure grassland feeding (see Box 7.4).

Use of roughage

In organic farming much emphasis is put on roughage feeding, which may have great impact on health and disease patterns. In cattle, a high proportion of roughage will often be favourable to the rumen environment and will result in less metabolic disease (e.g. Danish Cattle Advisory Board 1998). Recent observations on ruminal acidosis suggest that problems may arise and need further investigation. In organic pig production, the use of roughage such as pH-lowering silage, may reduce the incidence of gastrointestinal bacterial infections like salmonella, dysentery and lawsonia, but increase the prevalence of nematodes (Petkevicius *et al*. 1999). The extensive use of roughage can be problematic due to its low energy density compared to most concentrates, as it may dilute ration energy density to a level too low for a high level of production, referring to the potential conflict described above with breeding for high production. This may present a higher risk associated with unbalanced diets, especially a shortage of energy combined with an excess of crude protein (Sundrum 2001). In Norway, this caused lower reproductive efficiency in cattle in the mid 1990s (Reksen *et al*. 1999), because commercial organic concentrates were not available and the farmers had to rely on home-grown forage. In most European countries, organic milk production varied between 80% and 95% of the level found in conventional herds, probably due to a lower energy level in the rations. In a Danish study, the level of subclinical ketosis in organic dairy herds was found to be at the same level as conventional, but occurring at a later stage of lactation than in conventional herds, despite the larger negative energy balance between production and feed-intake in organic herds (Vaarst 1995). This was explained by the accessibility to feed 24 hours per day, daily exercise and the feeding of offspring with roughage.

Challenges in tropical areas: feeding from 'organic by default' to 'organic as a goal'

Much of the existing organic livestock production takes place in relatively intensive production systems in Europe and North America, but we should also consider the potential development of organic production systems in other countries, such as in tropical countries. Many systems can almost be regarded as 'organic by default' except for the relatively extensive use of medical drugs in order to control vectorborne diseases (see *Animal disease treatment in organic animal husbandry*). Since many systems are based primarily on grazing, the possibilities from changing from 'organic by default' to 'organic by principle' will be discussed briefly below in relation to grazing. However, it is also relevant to discuss and explore other systems in relation to potential conversion to organic systems. In Box 7.1, we give an example of how a zero-grazing smallholder dairy system can potentially develop into an organic production system, using home-grown feed and developing from completely zero-grazing to partly pasture based. The challenge in many existing systems is to change from the reliance on importing feed concentrates onto the farm and to initiate the production of improved pasture and legumes for high production cows. Beside this, it is relevant to discuss the suitability of Holstein-Friesian cattle in tropical farming systems in terms of 'naturalness', disease resistance, supporting the local environment and recirculation.

The organic dilemma in monogastric animals: the protein sources

One particular area of concern is the feeding of protein to monogastric organic animals. In conventional production, current production relies on providing supplementary synthetic amino acids. Poultry has a high demand for sulfur-containing amino acids and pigs have a

Box 7.1 An example from East Africa: a well-balanced feed ration from improved pasture results from changing zero-grazing systems to grazing systems

Today's zero-grazing system

Zero-grazing systems are often placed in urban or periurban areas, or in villages where land priority is a culture of cash crops and human food. Dairy cows are normally crossbred between local zebu or boran and exotic breeds like Holstein Friesian.

Feed ration: Forage based on cut and carry grass is often poor quality from communal areas such as river beds and road sides, and residues from cash crops or human food crops (e.g. maize stover, rice straw and banana pseudostem). Concentrates are based on local (national) residues like maize bran and cottonseed meal.

Possible future 'organic' system, with daytime grazing

Feed ration: Forage could be based on short daytime grazing on cultured paddocks with a grass–legume mix, barn feeding with cultured (cut and carry) grass and leaves or twigs from a legume tree (e.g. *Calliandra*), hedges and residues from cash crops and human food (e.g. maize stover, rice straw, banana pseudostem, sweet potato vines). Depending on seasons, forage conservation (e.g. hay) may be necessary. As a result of improved forage quality, concentrate feeding can be kept to a minimum, and based on home-grown concentrates and/or on residues from organic human food production.

Bottlenecks to changing from zero-grazing

Many current zero-grazing systems are urban or periurban, with no land for grazing. Certified organic production makes the use of cut and carry forage from free 'communal' areas impossible. There is a limited market for certified products. Grazing land is often far away from the fresh milk market. Zero-grazing offers some advantages with regard to disease prevention (e.g. freedom from some vectorborne and parasitic diseases).

high demand for essential amino acids. It is impossible to cover this requirement through 'natural feed stuffs', and these productions, therefore, rely on high nutrient density imported feed. It is difficult to compensate for this shortcoming, and more research as well as experience is needed to develop strategies that meet all requirements regarding animal health, welfare and production. Breeding goals emphasising this balance rather than only high animal production must be preferred as the most sustainable long-term solution to these problems.

Feeding for animal health and welfare: the method of feeding

In addition to the composition of the feed ration and the high quality of feed, clean drinking water should be included in the considerations regarding feeding when animal health and welfare is a primary goal of the herd, as well as the method of feeding. In Box 7.2, an example

Box 7.2 The flat rate feeding strategy as applied in dairy production systems in Denmark

The flat rate feeding principle is illustrated in Figure 7.1. Within a herd all cows are given a fixed amount of concentrates irrespective of daily milk yield, and roughage is fed *ad libitum*. The length of the period with fixed amount of concentrates is typically from calving to 24 weeks postpartum, but on some farms it lasts the entire lactation. Kristensen and Kristensen (1998) have shown that the slope of the lactation curve is lower in organic farming than in conventional farming, and argue that one of the reasons is a long period with fixed amounts of concentrates and a high intake of energy from roughage. The high persistence was especially seen for cows in the first lactation, where the daily milk yield only dropped 0.33 kg per month from 6 to 36 weeks postpartum in the organic herds.

Roughage quality is a very important factor when using the flat rate feeding strategy. The variation between cows in energy demand has to be met by variation in roughage intake.

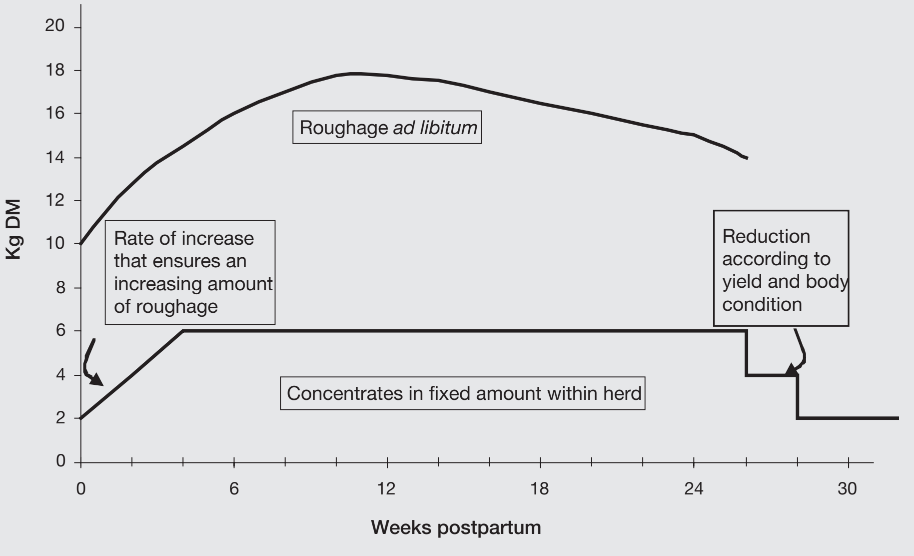

Figure 7.1 Illustration of the flat rate feeding strategy, based on *ad libitum* feeding of roughage and a fixed amount of concentrate.

of a feeding strategy in Danish dairy herds is given, supporting the intake of roughage, which is particularly suitable for an organic farm.

Also, feeding in order to meet the special nature and demands of each animal species is needed. Different animal species have different needs for combining eating behaviour with other types of behaviour such as rooting or foraging (Waiblinger *et al.* 2004). Incorporating this concept into animal production systems means that animals, in accordance with their natural behaviour, should be given the opportunity to remain in groups, have access to eating at the same time, and be given as much freedom of choice as possible to drink, eat, lie down and move. Transition periods such as between summer and winter, or from lactation (or production) to dry periods should be gentle.

Grazing and grassland management

Almost 60% of the certified organic land area is grassland (Hamm and Gronefeld 2004). On a global level, many challenges exist in terms of grassland farming under different conditions (not only certified organic), ranging from sub-Saharan Africa, where 50% of farmers are either pastoralists or agropastoralists, and where much land is communal grazing areas, partly involving transhumance. In European countries such as Switzerland, Romania, Poland, Scotland and Norway, different grazing systems exist on large land areas, whereas other countries such as Denmark, the Netherlands and the UK have systems where detailed planning of grassland and other crops is necessary. This is important in order to maintain harmony of a farm level with very limited land in relation to the number of animals, including limited permanent grasslands (Younie *et al.* 2004). In Box 7.3, an example is given of feeding and the resulting milk production based on management of an integrated crop–livestock system with an intensive dairy herd in Denmark.

In Box 7.4, an example is given of Australian organic grassland farming as an example of organic production of beef based on pure grazing systems. The rangelands of Australia cover around 70% of the continent. Livestock production is the most widespread use, being largely an ‘organic-by default’ production system involving minimum inputs and low intensity production with native pasture species and in some instances, improved or supplemented pasture. Stock handling is kept to a minimum, with cattle being mustered on average twice per year, which may include using horses, motorbikes, vehicles, helicopters or light planes. The carrying capacity of some types of country can be as low as one steer per square kilometre. The Channel Country is a significant part of the internally draining Lake Eyre Basin where rain falls in the subtropics and traverses hundreds of kilometres through arid areas to drain into Lake Eyre, bordered by deserts. Livestock are predominantly beef cattle (*Bos taurus* or *Bos indicus*) with sheep in the semi-arid zones. *Bos indicus* breeds prevail in the humid tropics and subtropics, thereby minimising issues associated with cattle tick or lice.

Health promotion and the human role in organic animal herds

In *Chapter 8*, Lund discusses the role of humans in relation to the welfare of the individual animals on a farm. In regard to health and wellbeing, knowledge of the behavioural patterns of the animals is important, as well as the intense surveillance of the animals and the herd combined with immediate intervention when necessary. In some systems with large flocks of animals, for example in Australian beef herds, the individual animal may be living a highly natural life, but it is not as closely looked after as an individual animal in more intensive production systems. In the latter case, closer proximity means the farm operator is more likely to observe problems and intervene early, reducing possible prolonged suffering.

Box 7.3 High milk yield can be obtained from large amounts of pasture and silage of high quality

Organic dairy production can be combined with high milk production, based on cows with high genetic merit and *ad libitum* feeding of roughage as silage or pasture (Mogensen and Kristensen 1999, Nicholas *et al.* 2004). The marginal effect on milk production of increasing amounts of concentrates is often low, when high quality roughage is fed *ad libitum*. This was confirmed in a long-term experiment by Sehested *et al.* (2003), where milk production increased only 0.73 kg milk/kg extra dry matter of concentrates.

An example of feeding and resulting milk production in a Danish organic herd with all year round calving is shown in Figure 7.2. The average herd production was 9000 kg milk. Daily feed intake and milk production is averaged for all cows (lactating and dry) in the herd.

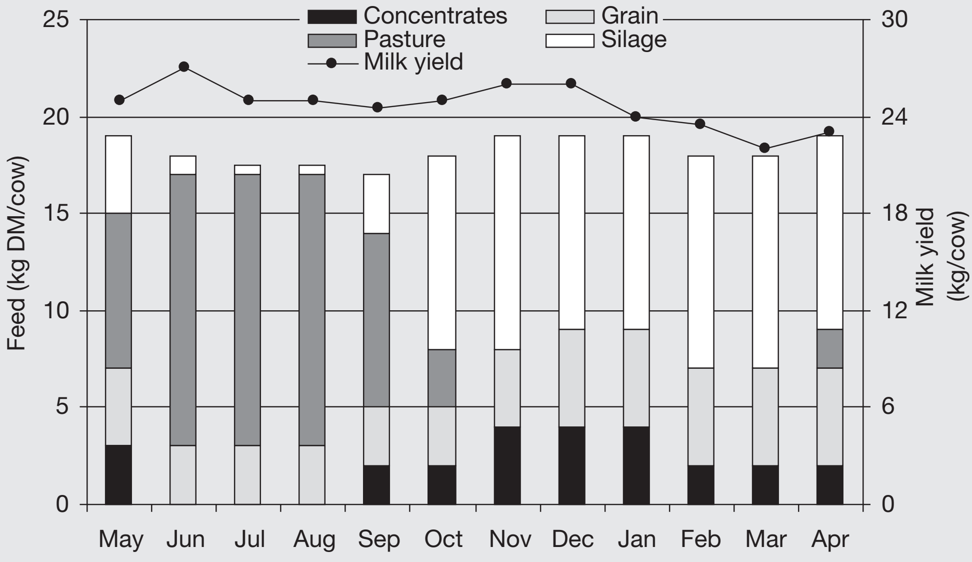

Figure 7.2 An example of feeding a mixture of concentrates, pasture, grain and silage and resulting milk production in a Danish organic herd with all year-round calving.

In any farming system, it is the responsibility of the farmer to ensure that no animals suffer, and that they have sufficient feed and water. In organic farming, because the goals for animal health and welfare emphasises 'naturalness', there is the further obligation to ensure that animals have their natural and species-specific needs fulfilled as far as possible. This adds some specific demands to the daily as well as the strategic management of the animals and the herd (Vaarst *et al.* 2004b). Letting animals live a flock life and an outdoor life means adding risks to their lives compared to a 'safe and uncomplicated life' such as in individual housing or cage systems, where inspection is easier. In addition to the importance in disease management to intervene immediately when necessary, the farmer develops a specific role for the human care-taker, in the organic herd on the strategic level. The farmer creates a framework for the animals that allows them to live a life where natural needs are fulfilled to a large extent, and on the daily management level to work within this framework by inspecting the animals and their surroundings carefully, but only intervening and 'becoming visible' when there is some kind of crisis.

Box 7.4 Organic beef production in the OBE Beef organisation in the Channel Country in Australia, where the climatic and environmental conditions almost formed an organic-by-default production

OBE Beef is an alliance of 40 individual cattle producers formed in 1996 and centred around the unique Channel Country of southwest Queensland and northeast South Australia. OBE Beef manages an area of more than seven million hectares with a combined herd in excess of 100,000 cattle. OBE Beef is Australia's largest organic beef supplier, involving the partners in all stages of the supply chain from production through to marketing and promotion.

The decision to obtain certified organic production status was considered by the OBE Beef founding members to be a logical extension to their current low intensity production systems. The certification process for individual properties took up to three years to meet International Federation of Organic Agriculture Movements (IFOAM) standards as accredited by the National Association for Sustainable Agriculture in Australia (NASAA) (AFFA 2000). Existing management systems were adapted to an organic management plan covering record keeping, physical structures and maintenance of property resources (e.g. testing the soil for chemical contamination, erection of approved fences and stock handling facilities such as yards and loading ramps, and the provision of good quality water supplies). Ongoing monitoring of the condition of the natural resources is fundamental to OBE Beef operations, ensuring environmental sustainability. Any supplementary feed brought onto the properties, such as hay, had to be organically grown and stored appropriately.

A high standard of animal husbandry has to be maintained. Stud bulls are introduced into the organically accredited herds following appropriate quarantine. The herds are otherwise self-replacing. An electronic identification system for individual animals completes the quality traceability system.

Cattle are processed at a fully certified abattoir near Toowoomba, Queensland, a distance of up to 1600 km for some partner properties. The transportation and slaughter processes are rigorously controlled to avoid contamination and ensure separation from non-organic stock. Specific standards were developed for transport and handling of the stock over this distance, and endorsed by NASAA.

Measures adopted to ensure the continuity of production included production of organic hay and agreements to agist cattle on certified organic properties closer to the processing plant during dry times.

With assistance from the Australian Government, OBE Beef originally targeted the markets of Japan, learning valuable marketing skills and developing important relationships with their Japanese trading partners. Their first export shipment to Japan was in 1998, including taste testing and customer seminars presented by some of the OBE partners. Sales have continued to grow, with export countries now including USA, some European countries as well as sections of the Australian domestic market. The volume of organic beef exports is around 0.1% of Australia's total beef exports, providing considerable opportunities for further expansion.

Animal disease treatment in organic animal husbandry

Intervention in any case of potential crisis: critically important

One aim of organic farming is to reduce the use of synthetic chemical substances. However, disease must be treated for animal welfare reasons, and the most effective treatment will often be considered to be biomedical veterinary medicine of synthetic chemical origin. The compromise in European countries regarding the use of synthetic chemical veterinary medicine, is to encourage health promotion and non-medical disease prevention by demanding a two to three times prolonged withdrawal time after treatment, and a limited number of treatments per animal per year or lactation.

The farmer has a responsibility to act and intervene appropriately in relation to each individual animal in the case of disease. It is not a question of whether to intervene, but about which form of treatment, if any, will best prevent suffering and aid recovery. Instead of thinking only of disease treatment, options for supportive treatments should be considered. These comprise ways of supporting the animal in an unbalanced health state to recover (Vaarst *et al.* 2004a). Taking dairy production as an example, a solution could be milking by hand between machine milkings very early in a mastitis case; providing extra bedding in critical situations (e.g. after calving), using soap and water to clean infected wounds, traumas or some claw disorders (e.g. abscesses). Longer term strategies include culling, drying off single udder glands, and letting cows with high somatic cell counts stay together with suckling calves for a short or long period. Careful inspection of animals and their products (e.g. milk) is of crucial importance, and immediate reaction to any critical condition is the most important factor. Many of these interventions have relatively high labour demands, such as udder massage and milking by hand, which may limit their relevance in, for example, intensive northwest European farming systems.

Previous and ongoing Danish studies show that the basic ideas of organic farming can be seen as stimulating a great effort to improve the health situation in herds, including disease management by farmers. In interviews, many organic farmers have described a 'conversion in the herd and heart', which made them take responsibility for their own animals in a new way instead of just calling the veterinarian (Vaarst 1995, Vaarst *et al.* 2003).

Alternatives to conventional disease-treatment methods

In the US organic livestock standards, there is a complete prohibition of biomedical product use, which emphasises the need for the development of sustainable treatment methods for organic animals. EC Regulation No. 1804/1999 states that 'diseases of organic farm animals must preferably be treated with phytotherapeutic products or homoeopathic solutions provided that their therapeutic effect is effective for the species of animal and the condition for which the treatment is intended'. Phytotherapy represents a wide range of different methods and substances primarily based on plant products, and will in many cases be defined within the framework of folk medicine (Kleinman 1981). Homoeopathy is a medical school with its own theory and practice, and presents an approach to health and disease very different from that of conventional biomedicine. In several European countries, there has been a discussion of the legal status of phytotherapeutic as well as homoeopathic products, as they are not registered for use in production animals, which forms a bureaucratic restriction on the development of these methods. Development of various research frameworks and study designs have been discussed (Hektoen 2004, Fossing 2005), to create a better understanding of the mechanisms of this treatment method. Acupuncture and chiropractic are other options for the treatment of production animals. As with any treatment method, they will demand a relatively high level of specific education. Acupuncture treatment will often require a veterinarian, and sometimes a treatment will take 20–60 minutes, which limits its use in many situations. In production animals, acupuncture has been shown to be particularly useful in reproduction disorders of all kinds including birth situations.

The involvement of the veterinary advisers

In relation to health promotion and disease prevention as well as disease management, the role of the veterinarian and other animal health professional advisers should be to support the farmers in fulfilling their goals for the herd as well as organic goals. In the UK, health planning is a part of conversion to organic farming (Hovi 2003) and in Switzerland, a research and development project involving health planning in several organic dairy herds has pointed to the importance of the dialogue between farmers and advisers to develop organic strategies for better health and less disease (Walkenhorst *et al.* 2004). In Denmark, more studies have shown that farmers, to a small extent only, involve their veterinarian in the development of the organic herd, and that one major reason is a lack of understanding and support from the veterinarians, who do not consider 'organic farming' to be something special that they should relate to (Vaarst *et al.* 2003, 2005). Ellis and Hovi (2003) concluded in a working group report at a European workshop, that veterinarians seemed to have a general lack of knowledge and to be sceptical of organic farming. Schumacher (2004) concluded that, seen from a farmer's point of view, the advisory system in organic farming is not adequately specialised. Consequently, a great potential seems to exist in terms of development of collaboration on strategies for health promotion, methods of alternative disease management, as well as ways of interacting for farmers and animal health professionals. One recent and apparently very fruitful development in the organic environment seems to be the adaptation of the so-called Farmer Field School approach from African and Asian countries to Danish organic dairy herds. The formation of farmer groups, where farmers advise fellow farmers, seems to support the search for innovative solutions to health and disease problems, and thereby improves the health situation on the farm.

From organic livestock production to organic animal food production: the whole food chain

Organic food: process quality and product quality

Two quality criteria can be used in organic livestock production:

1 process quality, a description of the way the food has been produced (e.g. animal welfare, environmental care); the things consumers 'know' about the product and which add a certain quality to it, influencing their choice of this product; and
2 product quality, which covers nutritional and sensory qualities, food safety qualities and possible health benefits.

Both aspects are important for organic food products, and both can be improved at the farm level through feeding and animal welfare related routines. Kouba (2003) concluded that there are no consistent differences in nutritional qualities between organic and conventional animal products, and no clear evidence that organic food contains more mycotoxins or is more or less microbiologically safe than conventional food (see *Chapter 13*). Consumers are also motivated to buy organic food to avoid genetically modified organisms and food irradiation.

Zoonotic diseases and food safety aspects

Several infectious agents can be transmitted from farm animals to humans through the food chain and cause disease (zoonoses). These diseases are often associated with highly industrialised livestock production, but they also can occur in organic production. In particular, the risk for zoonotic infections with outdoor reservoirs, such as *Campylobacter* (in poultry), is increased. Another important zoonotic infection is *Salmonella*, although little difference in incidence of this infection is reported between organic and conventional production, in both poultry and pigs. However, several factors may reduce the risk: different feeding regime, lower stocking rate, grazing, feeding roughage (e.g. silage with a low pH). *Salmonella* bacteria may survive outdoors for up to one year, and therefore the resting period of pastures may be important. For example, Rodenburg *et al.* (2004) found 35% of organic poultry sampled positive in the Netherlands for *Campylobacter* and 13% for *Salmonella*. Von Borell and

Sørensen (2004) found that the measures for prevention of certain diseases and the risk factors for food contamination like *Salmonella* can be considered as premature. Trichinosis is an example of a zoonotic helminth infection that may have a reservoir in wild pigs and foxes. The risk that such an infection is introduced into outdoor organic pig herds is substantially higher than in indoor production (Jensen and Baggesen 2005), likewise toxoplasmosis (Kijlstra 2004). Bovine spongiform encephalopathy (BSE) is now regarded as a probable zoonosis. The disease was spread by recycling meat and bone meal made from infected sheep or cattle as feed for livestock, and had originated in the early 1970s from a novel source, possibly a cow or other animal that had developed the disease as a result of a genetic mutation (Phillips *et al*. 2000). Since BSE has been related to the consumption of bone meal, and this has not always been prohibited in non-organic herds, there might be a risk of BSE in animals that have been imported from conventional herds.

Biosecurity and risks connected to animal management

Certain production conditions present particular biosecurity risks. For example, where disease incubation or weed dispersal are difficult to control such as in intensive dairy systems or hill farming in the UK (Keatinge and Elliott 1997, van de Ven *et al*. 2003), there will be a greater likelihood of harmful organisms proliferating. The movement of animals between farms, often over long distances, adds additional biosecurity and animal welfare concerns. In many European countries animals for slaughter are transported from farms in remote areas to abattoirs, some of which are organically certified, or they are transported between farms and grazing areas. When discussing the potential for development of organic production in areas where this is not yet established, the export and import of animals, the transhumance and the use of communal grazing areas should be profoundly analysed and managed in the context of each specific region.

The NAHWOA Recommendations (Hovi 2004) call for the standards to give greater emphasis to biosecurity. However, smaller flock sizes, low stocking rates and access to outdoor environments reduce the potential for other diseases associated with dense populations, high levels of inputs, enclosed environments and restricted movement.

Conclusions and future perspectives

Several challenges exist in animal health for organic livestock production, both in established organic farms and in areas where organic farming is developing. The prevalence of disease is still critical in many organic farming systems, and sustainable ways of managing organic herds still need further development.

One major challenge for a more global development of organic farming is to further infiltrate the concept of ‘alternative systems’ into the many diverse existing farming systems. For example, communal grazing is a way of livestock production commonly practiced in large areas of the world, and this needs to be considered when converting to organic farming. It may involve conversion on the ‘communal level’ rather than the farm level in some cases.

Many farming communities are extremely resource poor. Even though there might not be a particular market for ‘organic products’ from or in these communities, organic practices still may be relevant to support both environmental and economic sustainability of the area; this may include using local resources and not relying on import of feed, drugs and animal breeds. They may serve as local beacons for a sustainable development.

Disease management should be based on health promotion efforts and disease prevention strategies. When disease occurs, rapid intervention using alternative strategies and disease treatment methods if possible, is critical. Veterinary services and extension need to be ‘converted’ to a much greater extent to support the organic approach to animal health and welfare.

The role of humans in the organic herds is to both support the possibilities for the animals to perform their species-specific natural behaviour, giving them as many opportunities as possible to live a 'natural life' (e.g. flock life, outdoor life, mother–offspring relations), and to be care-takers who support animal wellbeing by fulfilling their nutritional requirements and who intervene whenever necessary to avoid a potential crisis.

With regard to organic feeding, many of the challenges regarding home-grown or locally grown, organic feed can be met by optimal crop rotation systems, high quality feed production in terms of pasture management and harvest at the right time, choice of the best crops, conservation and storage under optimal conditions. However, some import into the farm seems necessary, such as trace elements and minerals. The reliance by monogastric animals on synthetic amino acids in conventional farming systems needs to be met in organic systems using more sustainable, long-term strategies, including breeding and production goals. Differences between countries and regions with regard to farming systems seem bigger than the general difference between conventional and organic livestock systems.

References

AFFA 2000. *OBE Organic Rangeland Beef*. Food and Agribusiness Industries Division, Department of Agriculture, Fisheries and Forestry, Canberra. <http://www.affa.gov.au/corporate_docs/publications/pdf/food/nidp/obe_organic_rangeland_beef.pdf>.

Bestman, M. 2000. The role of management and housing in the prevention of feather pecking in laying hens. In: Hovi, M. and Bouilhol, M. (eds) *Human–Animal Relationship: Stockmanship and Housing in Organic Livestock Systems. Proceedings of the Third NAHWOA Workshop, Clermont-Ferrand, 21–24 October 2000*. University of Reading, Reading. pp. 79–88.

Danish Cattle Health Advisory Board 1998. Produktionsmæssige konsekvenser af omlægning fra konventionel til økologisk produktion. *LK meddelelser* 178.

Danish Poultry Council 2002. *Annual Report*. The Danish Poultry Council, Trommesalen.

Ebbesvik, M. and Løes, A.K. 1994. Organic dairy production in Norway – feeding, health, fodder production, nutrient balance and economy – results from the 30 farm project 1989–1992. In: Granstedt, A. and Koistinen, R. (eds) *Converting to Organic Agriculture*. Nordic Association of Agricultural Scientists, Stockholm. p. 35–42.

Ellis, K. and Hovi, M. 2003. Attitudes of veterinary and advisory staff to organic livestock production: identification of problems and recommendations. Working Group Report. In: Hovi, M., Martini, A. and Padel, S. (eds) *Socio-Economic Aspects of Animal Health and Food Safety in Organic Farming Systems. Proceedings of the 1st SAFO Workshop, 5–7 September 2003, Florence, Italy. Sustaining Animal Health and Food Safety in Organic Farming*. University of Reading, Reading. pp. 221–223.

Fossing, C. 2005. Researching alternative medicine for treatment of mastitis in cattle: possibilities and limitations. PhD thesis (submitted August 2005), The Royal Veterinary and Agricultural University, Copenhagen, Denmark and Danish Institute of Agricultural Sciences, Tjele.

Früh, B. 2004. Feeding strategies in Swiss organic farming to improve food quality and animal health. In: Hovi, M., Sundrum, A. and Padel, S. (eds) *Organic Livestock Farming: Potential and Limitations of Husbandry Practice to Secure Animal Health and Welfare and Food Quality. Proceedings of the 2nd SAFO workshop 25–27 March 2004, Witzenhausen, Germany. Sustaining Animal Health and Food Safety in Organic Farming*. University of Reading, Reading. pp. 55–57.

Gunnarsson, S., Keeling, L.J. and Svedberg, J. 1999. Effects of rearing factors on the prevalence of floor eggs, cloacal cannibalism and feather pecking in commercial flocks of loose housed laying hens. *British Poultry Science* 40: 12–18.

Gunnarsson, S., Yngvesson, J., Keeling, L.J. and Forkman, B. 2000. Rearing with early access to perches impairs spatial skills of laying hens. *Applied Animal Behaviour Science* 67(3): 217–228.

Hamm, U. and Gronefeld, F. 2004. *The European Market for Organic Food: Revised and Updated Analysis*. University of Wales, Aberystwyth.

Hardeng, F. and Edge, V.L. 2001. Mastitis, ketosis and milk fever in 31 organic and 93 conventional Norwegian dairy herds. *Journal of Dairy Science* 84: 2673–2679.

Hektoen, L. 2004. *Homoeopathic Treatment of Farm Animals. Studies of Utilisation, Effects and Implications for Animal Health and Welfare*. PhD thesis, Department of Production Animal Clinical Sciences, Norwegian School of Veterinary Science, Oslo.

Hermansen, J., Strudsholm, K. and Horsted, K. 2004. Integration of organic animal production into land use with special reference to swine and poultry. *Livestock Production Science* 90: 11–26.

Honing, Y. (ed.) *Book of Abstracts No. 11. EAAP – 5th Annual Meeting, Uppsala, Sweden, 5–8 June 2005*. Wageningen Academic Publishers, Wageningen.

Hoste, H., Athanasiadou, S., Paolini, V., Jackson, F., Coop, R.L., Kyriazakis, I., Barrow, E., Fouraste, L., Valderrabano, J., Uriarte, J., Larsen, M., Mejer, H. and Thamsborg, S. 2004. Nutritional aspects of bioactive forages for worm control in organic sheep and goats. In: Hovi, M., Sundrum, A. and Padel, S. (eds). *Organic Livestock Farming: Potential and Limitations of Husbandry Practice to Secure Animal Health and Welfare and Food Quality. Proceedings of the 2nd SAFO workshop 25–27 March 2004, Witzenhausen, Germany. Sustaining Animal Health and Food Safety in Organic Farming*. University of Reading, Reading. pp. 123–127.

Hovi, M. 2003. *Approaches to Mastitis Control in Well-Established Organic Dairy Herds in England and Wales*. PhD thesis, Veterinary Epidemiology and Economics Research Unit. University of Reading, Reading.

Hovi, M. 2004. A European Network for Animal Health and Welfare in Organic Agriculture (NAHWOA). In: Vaarst, M., Roderick, S., Lund, V. and Lockeretz, W. (eds) *Animal Health and Welfare in Organic Agriculture*. CABI Publishing, Wallingford. pp. 405–418.

Hovi, M. and Roderick, S. 1999. Mastitis in organic dairy herds – results of a two-year survey. In: *Mastitis. The organic perspective. Proceedings of a Conference on Current Research, Prevention, Treatment and Alternative Solutions for the Dairy Sector. Friday 3rd September 1999*. Soil Association/University of Reading/MAFF, Bristol. p. 6.

Jensen, A.N. and Baggesen, D.B. 2005. Salmonella infection risk associated with outdoor organic pig production. In: Hovi, M., Walkenhorst, M. and Padel, S. (eds). *Systems Development: Quality and Safety of Organic Livestock Production. Proceedings of the 4th SAFO workshop 17–19 March 2005, Frick, Switzerland*. Sustaining Animal Health and Food Safety in Organic Farming, University of Reading, Reading. pp. 87–93.

Jørgensen, K.F., Kjeldsen, A.M., Strudsholm, F. and Vestergaard, M. 2005. Factors causing a higher level of liver abscesses in organic compared with conventional dairy herds. In: van der Honing, Y. (ed.) *Book of Abstracts No. 11 of the 56th Annual Meeting of the European Association for Animal Production. Uppsala, Sweden, 5–8 June 2005*. Wageningen Academic Publishers, the Netherlands. pp. 310.

Keatinge, R. 1996. *Controlling Internal Parasites without Anthelmintics*. A review prepared for Conservation and Woodland Policy Division, Ministry of Agriculture, Fisheries and Food, UK.

Keatinge, R. and Elliott, J. 1997. *Organic Sheep and Beef Production in the Hills and Uplands. Project Report (1997) Fourth Year of Organic Production*. ADAS Redesdale, Newcastle upon Tyne.

Kijlstra, A. 2004. *Toxoplasma gondii* infection in organic pig production systems. In: Hovi, M., Zastawny, J. and Padel, S. (eds) *Enhancing Animal Health Security and Food Safety in Organic Livestock Production. Proceedings of the 3rd SAFO Workshop 16–18 September 2004, Falenty, Poland*. Sustaining Animal Health and Food Safety in Organic Farming, University of Reading, Reading. pp. 39–46.

Kleinman, A. 1981. *Patients and Healers in the Context of Culture. An Exploration of the Borderland between Anthropology, Medicine, and Psychiatry.* University of California Press, Berkeley.

Kouba, M. 2003. Quality of organic animal products. *Livestock Production Science* 80: 33–40.

Kristensen, I.S. 1998. Økologisk æg-, kød- og planteproduktion 1996/97. In: *Studier i økologiske jordbrugssystemer*. DJF-report. 1: 95–166.

Kristensen, T. and Kristensen, E.S. 1998. Analysis and simulation modelling of the production in Danish organic and conventional dairy herds. *Livestock Production Science* 54: 55–65.

Kugelberg, C. and Johansson, G. 2001. Infektionssjukdomar och ektoparasiter hos slaktsvin. *Svensk Veterinärtidning* 53(4): 197–204.

Lampkin, N. 1997. *Organic Poultry Production*. University of Wales, Aberystwyth.

Lauritsen, H.B., Sørensen, G.S. and Larsen, V.A. (2000) Organic pig production in Denmark. In: *Ecological Animal Husbandry in the Nordic Countries. Proceedings from NJF-seminar No. 303, 1999. DARCOF-report No. 2*. pp. 113–118.

Lindqvist, A., Ljungström, B.L., Nilsson, O. and Waller, P.J. 2001. The dynamics, prevalence and impact of nematode parasite infections in organically raised sheep in Sweden. *Acta Veterinaria Scandinavica*. 42: 377–389.

Lindsjö, J. 1996. *Grisar ute! En översikt av rutiner och hälsoläge i svenska besättningar med slaktsvinsuppfödning utomhus*. Department of Animal Hygiene, Swedish University of Agricultural Sciences, Skara.

Lund, V. and Algers, B. 2005. Research on animal health and welfare in organic farming – a literature review. *Livestock Production Science* 80: 55–68.

Mogensen, L. and Kristensen, T. 1999. Private farms for research in organic milk production in Denmark. In: Gagnaux, D., Daccord, R., Gibbon, A., Poffet, J.R. and Sibbald, A.R. (eds) *Fifth International Livestock Farming Systems Symposium. Posieux, Switzerland, 19–20 August*. European Association for Animal Production. pp. 6–101.

Nauta, W.J., Baars, T. and Bovenhuis, H. 2005. Genotype environment interactions for milk production traits between conventional and organic dairy farming in the Netherlands. *Biological Agriculture and Horticulture* 22: 217–249.

Offerhaus, E.J., Baars, T. and Grommers, F.J. 1993. *Gezonheid en vruchtbaarheid op biologische bedrijven farms*. Louis Bolk Institute, Driebergen.

Olsson A.C., Svendsen, J. and Sundelof, J.A. 1996. *Ekologisk svinproduktion*. Specialmeddelandem, Institutionen for Jordbrukets Biosystem och Teknologi, Sveriges Lantbruksuniversitet, Uppsla.

Parrott, N., Olesen, J.E. and Høgh-Jensen, H. 2005. Certified and non-certified organic farming in the developing world. In: Halberg, N., Alrøe, H.F., Knudsen, M.T. and Kristensen E.S. (eds) *Global Development of Organic Agriculture: Challenges and Promises*. CABI Publishing, Wallingford. pp. 153–180.

Pedersen, M.A., Thamsborg, S.M., Fisker, C., Ranvig, H. and Christensen, J.P. 2003. New production systems: evaluation of organic broiler production in Denmark. *Journal of Applied Poultry Research* 12: 493–508.

Petkevicius, S., Nansen, P., Knudsen, K.E.B. and Skjøth, F. 1999. The effect of increasing levels of insoluble dietary fibre on the establishment and persistence of *Oesophagostomum dentatum* in pigs. *Parasite* 6: 17–26.

Phillips of Worth Matravers, Lord, Bridgeman, J. and Ferguson-Smith, M. 2000. *The Inquiry into BSE and Variant CJD in the United Kingdom*. Ministry of Agriculture, Fisheries and Food, London. <http://www.bseinquiry.gov.uk/>.

Reksen, O., Tverdal, A., and Ropstad, E. 1999. A comparative study of reproductive performance in organic and conventional dairy husbandry. *Journal of Dairy Science* 82: 2605–2610.

Rodenburg, T.B., Arkel, M.C.V. and Kwakkel, R.P. 2004. Campylobacter and Salmonella infections on organic broiler farms. *NJAS-Wageningen Journal of Life Sciences* 52: 101–108.

Roderick, S. and Hovi, M. 1999. *Animal Health and Welfare in Organic Livestock Systems: Identification of Constraints and Priorities. A Report to the Ministry of Agriculture, Fisheries and Food*. University of Reading, Reading.

Roderick, S., Short, N. and Hovi, M. 1996. *Organic Livestock Production - Animal Health and Welfare Research Priorities*. VEERU, University of Reading, Reading.

Schumacher, U. 2004. Animal welfare and health problem areas from an organic farmer's point of view. In: Hovi, M., Sundrum, A. and Padel, S. (eds) *Organic Livestock Farming: Potential and Limitations of Husbandry Practice to Secure Animal Health and Welfare and Food Quality. Proceedings of the 2nd SAFO workshop 25–27 March 2004, Witzenhausen, Germany*. Sustaining Animal Health and Food Safety in Organic Farming, University of Reading, Reading. pp. 25–16.

Sehested, J., Kristensen, T. and Søegaard, K. 2003. Effect of concentrate supplementation level on production, health and efficiency in an organic dairy herd. *Livestock Production Science* 80: 153–165.

Sundrum, A. 2001. Organic livestock farming – a critical review. *Livestock Production Science* 67: 207–215.

Svensson, C., Hessle, A. and Höglund, J. 2000. Parasite control methods in organic and conventional dairy herds in Sweden. *Livestock Production Science* 66: 57–69.

Thamsborg, S.M., Larsen, M., Christensen, L.P., Hoste, H., Kyriazakis, I., Jackson, F., Waller, P., Eysker, M. and Valderrabane, J. 2005. WORMCOPS – worm control in organic production systems for small ruminants in Europe: towards the implementation of non-chemical sustainable approaches (EU project QLK5-CT-2001-1843). In: Hovi, M., Walkenhorst, M. and Padel, S. (eds) *Systems Development: Quality and Safety of Organic Livestock Production. Proceedings of the 4th SAFO workshop 17–19 March 2005, Frick, Switzerland*. Sustaining Animal Health and Food Safety in Organic Farming, University of Reading, Reading. pp. 185–187.

Thamsborg, S.M., Roderick, S. and Sundrum, A. 2004. Animal health and diseases in organic farming: an overview. In: Vaarst, M., Roderick, S., Lund, V. and Lockeretz, W. (eds) *Animal Health and Welfare in Organic Agriculture*. CABI Publishing, Wallingford. pp. 227–252.

Thamsborg, S.M., Roepstorff, A. and Larsen, M. 1999. Integrated and biological control of parasites in conventional and organic farming systems. *Veterinary Parasitology* 84: 169–186.

Vaarst, M. 1995. *Sundhed og sygdomshåndtering i danske økologiske malkekvæg besætninger*. PhD thesis, Clinical Institute, The Royal Veterinary and Agricultural University, Copenhagen.

Vaarst, M. and Enevoldsen, C. 1994. Disease control and health in Danish organic dairy herds. In: *Proceedings of the 4th Zodiac Symposium, Biological Basis of Sustainable Animal Production, April 13–15 1993, Wageningen*. European Association for Animal Production, pp. 211–217.

Vaarst, M., Bennedsgaard, T.W., Klaas, I., Nissen, T.B., Thamsborg, S.M. and Østergaard, S. 2005. Development and daily management of an explicit strategy of nonuse of antimicrobials in 12 Danish organic dairy herds. (submitted)

Vaarst, M., Feenstra, A.A., Roepstorff, A., Hoegedal, P., Larsen, V.A., Worm, R., Hermansen, J.E. and Lauritsen, H.B. 1998a. Sundhedsforhold ved økologisk svineproduktion illustreret og diskuteret med udgangspunkt i en besætningscase. In: *Forskning i Økologisk Svineproduktion, FØJO Report 1*. pp. 33–45.

Vaarst, M., Hindhede, J. and Enevoldsen, C. 1998b. Sole disorders in conventionally managed and organic dairy herds using different housing systems. *Journal of Dairy Research* 65: 175–186.

Vaarst, M., Martini, A., Bennedsgaard, T.W and Hektoen, L. 2004a. Approaches to the treatment of diseased animals. In: Vaarst, M., Roderick, S., Lund, V. and Lockeretz, W. (eds) *Animal Health and Welfare in Organic Agriculture*. CABI Publishing, Wallingford. pp. 279–303.

Vaarst, M., Thamsborg, S.M., Bennedsgaard, T.W., Houe, H., Enevoldsen, C., Aarestrup, F. and De Snoo, A. 2003. Organic dairy farmers decision making in the first two years after conversion in relation to mastitis. *Livestock Production Science* 80: 109–120.

Vaarst, M., Wemelsfelder, F., Seabrook, M., Boivin, X. and Idel, A. 2004b. The role of humans in the management of organic herds. In: Vaarst, M., Roderick, S., Lund, V. and Lockeretz, W. (eds) *Animal Health and Welfare in Organic Agriculture*. CABI Publishing, Wallingford. pp. 205–225.

Von Borell, E. and Sørensen, J.T. 2004. Organic livestock production in Europe: aims, rules and trends with special emphasis on animal health and welfare. *Livestock Production Science* 90: 3–9.

Waiblinger, S., Baumgartner, J., Kiley-Worthington, M. and Niebuhr, K. 2004. Applied ethology: the basis for improved animal welfare in organic farming. In: Vaarst, M., Roderick, S., Lund, V. and Lockeretz, W. (eds) *Animal Health and Welfare in Organic Agriculture*. CABI Publishing, Wallingford. pp. 117–161.

Walkenhorst, M., Notz, C., Klocke, P., Spranger, J. and Heil, F. 2004. Udder health concepts that comply with organic principles – how to reduce therapies? In: Hovi, M., Sundrum, A. and Padel, S. (eds) *Organic Livestock Farming: Potential and Limitations of Husbandry Practice to Secure Animal Health and Welfare and Food Quality. Proceedings of the 2nd SAFO Workshop, 25–27 March 2004, Witzenhausen, Germany*. Sustaining Animal Health and Food Safety in Organic Farming, University of Reading, Reading. pp. 71–76.

Weinreich, L.L., Thamsborg, S.M., Jensen, A.M., Vaarst, M. and Rasmussen, J. 2005. Parasite control in Danish organic dairy herds and farmers' attitudes to agricultural production. In: Hovi, M., Zastawny, J. and Padel, S. (eds) *Enhancing Animal Health Security and Food Safety in Organic Livestock Production. Proceedings of the 3rd SAFO Workshop. 16–18 September 2004, Falenty, Poland*. Sustaining Animal Health and Food Safety in Organic Farming, University of Reading, Reading. p. 165.

Younie, D., Thamsborg, S.M., Ambrosini, F. and Roderick, S. 2004. Grassland management and parasite control. In: Vaarst, M., Roderick, S., Lund, V. and Lockeretz, W. (eds) *Animal Health and Welfare in Organic Agriculture*. CABI Publishing, Wallingford. pp. 309–328.

Zollitch, W., Kristensen, T., Krutzinna, C., MacNaeihde, F. and Younie, D. 2004. Feeding for health and welfare: the challenge of formulating well-balanced rations in organic livestock production. In: Vaarst, M., Roderick, S., Lund, V. and Lockeretz, W. (eds) *Animal Health and Welfare in Organic Agriculture*. CABI Publishing, Wallingford. pp. 329–356.

Chapter 8

Animal welfare and ethics in organic agriculture

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Introduction

Animal welfare is a question of the animal's quality of life (Sandøe 1999) and is an area of increasing concern in Western society. In the European Union (EU), animals were officially recognised as sentient beings in 1997, in the Treaty of Amsterdam (EUR-Lex 2003), with England, Austria and Norway being examples of countries implementing new and stricter animal welfare legislation. In the United States of America (USA), the large fast-food chains have joined efforts with the supermarkets to establish some animal welfare regulations for their suppliers (Brown 2004).

In organic farming, there is a tradition of animal welfare concerns (Niggli and Lockeretz 1996, Boehncke 1997, Roderick and Hovi 1999). The organic movement frequently identifies animal welfare as an important goal, but welfare is also an area where strong criticism regarding organic animal production has been expressed. While some have argued that organic animal husbandry represents the best possible welfare in contemporary farming, representatives from conventional agriculture have often been critical of the welfare of organic animals. Consumers have appreciated the organic way of raising animals (although this is not always reflected in the sales records of organic products, Magnusson *et al*. 2001), and animal welfare is regularly used as a positive marketing argument for organic animal products (Harper and Henson 2001).

The question has to be asked, what are the reasons for these diverging opinions regarding animal welfare in organic production systems? This issue will be examined in this chapter, evaluating the underlying values in organic farming and whether there is an animal welfare problem in organic farming.

Animal welfare and ethics

Although there is general agreement that animals should have a good quality of life, there is no agreement as to what this means in practice. A good example to illustrate this is the two dog owners who both claim they provide their pets with the best possible quality of life (Fraser *et al*. 1997). The first makes sure to give the dog nutritious food, extra vitamins and regular coat trimming and always keeps the dog leashed to avoid it getting run over by a car, eating something harmful or running away. The other dog owner is less concerned about a balanced diet or a well-trimmed coat. During long hikes, the dog runs loose and can play in the dirt and may occasionally find and eat rotten meat scraps. This owner wants the dog unleashed since this will allow it to behave naturally, and is prepared to take some risks to give the dog the joy of freedom. The difficult question is: which dog has the better quality of life?

Even if we turn to science for advice, it will not be possible to give an indisputable answer to the question. Of course it is necessary to get all possible information and knowledge regarding how certain conditions affect the animal's quality of life. However, animal welfare is not only a matter of facts. It is also a question of what is considered important in life (Tannenbaum 1991). Researchers and philosophers have for several decades attempted to establish one definition of animal welfare, but today there is a common understanding that animal welfare is not only about facts, but also about values. Consequently, the interplay between facts and values, or between science and ethics, makes a single definition impossible.

The practice of ethics (i.e. normative ethics) scrutinises our basic values: what we consider good or bad, right or wrong in life (Frankena 1963). Animal ethics in particular deals with the relationship between humans and animals and the norms that establish a good and right relationship. Fundamental questions such as the appropriate degree of welfare (do animals have a right to claims on welfare at all, or can they without further thought be used for human pleasure?) have to be addressed. If we decide that animals should be granted welfare, then in this world of limited resources, the next question to be answered is when is welfare 'good enough'?

Ethics also includes welfare quality: *what is* good quality of life for an animal? Therefore, when evaluating animal welfare issues in organic farming systems, we need to understand if particular organic 'values' can be used to help guide decisions regarding appropriate quantity and quality of animal welfare.

Organic values

Organic farmers are a heterogeneous group, having various goals and opinions. However, the development of organic farming, including standards for organic production, has been pursued by the organic movement based on some shared values. When the values of organic farming are discussed in this chapter, the values refer to those of the organic movement, not individual farmers. Organic farming has substantial roots in ecological and biological farming practices espoused in the early 20th century (e.g. Balfour 1943), and in the environmental movements from the 1970s and 1980s (Christensen 1998). Biodynamic farming is an exception, since it is based on the philosophy of Rudolf Steiner and his ideas about farming (Steiner 1929). However, in spite of this different philosophical background, practical biodynamic animal husbandry has much in common with that of other parts of the organic movement. Here biodynamic farming will not be further considered.

It is possible to relate basic values in organic farming to ethical theories (Lund and Röcklinsberg 2001, Verhoog *et al.* 2004). Such theories dealing with the human–animal or human–nature relationship are often roughly divided into four categories depending on their focus of moral concern (moral concern implies that humans in their actions must consider the interests or rights of those beings or entities encompassed by it). These categories include: *anthropocentric, sentientistic, biocentric* and *ecocentric* theories (Stenmark 2002):

1. anthropocentric theories argue that only humans have direct moral status;
2. sentientistic theories argue that all sentient beings have direct moral status;
3. biocentric theories defend the view that all living beings have direct moral status, regardless of sentience; and
4. ecocentric theories state that all species, ecosystems and other relevant features in nature have direct moral status.

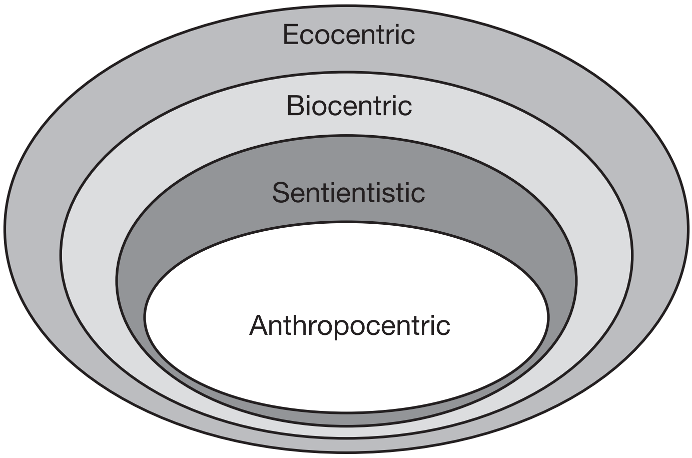

Figure 8.1 The four main categories for ethical theories dealing with questions regarding human–animal and human–nature relationships: anthropocentric, sentientistic, biocentric and ecocentric (Leopold 1949, Singer 1981). The idea of an evolution of ethics, however, has been discussed by several philosophers before Leopold and Singer such as Albert Schweizer, Thomas Huxley and Peter Kropotkin as well as by Charles Darwin).

As used here, these definitions do not deal with the question of intrinsic value, since it is theoretically possible to assign an entity intrinsic value but not direct moral concern; conversely, an animal can be the focus of moral concern but be independent of, or without, an intrinsic value (Röcklinsberg 2001).

The relationship among these different approaches is illustrated in Figure 8.1.

Aldo Leopold, a leading ecocentric theorist and biologist wrote: 'A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise' (Leopold 1949, pp. 224–225). This statement emphasises the holistic view and systems approaches associated with ecocentric ethics.

Organic farming is substantially based in ecocentric ethics (Alrøe *et al*. 2001, Lund and Röcklinsberg 2001, Verhoog *et al*. 2004). Ecocentric ethics largely responds to the same kind of issues that organic farming views as central, in particular the environmental concerns and the aim for a holistic view, and such a view has consequences for how 'quality of life' for farm animals is understood.

Is animal welfare an issue according to organic values?

Ecocentric ethics focus on nature as a whole, and the most important objective is to maintain or create well-functioning and sustainable ecosystems, which fits with the values espoused by the organic farming movement. From the principles of organic farming (IFOAM 2000), as well as IFOAM's published policy papers, it is clear that in general, the organic movement's primary goals focus on ecological sustainability rather than on animal welfare. Of the 17 general principles stated in the *IFOAM Basic Standards*, 13 deal with sustainability and only one explicitly with animal welfare.

The ecocentric approach essentially sees the wellbeing of individual animals living in the systems as secondary to the wellbeing of the system itself. For example, the organic view is that treating animals with chemical substances, antibiotics or other compounds that may affect the ecosystem negatively should be avoided, irrespective of the consequences for individual animals. The use of such substances is also considered unsustainable since the microorganisms will eventually become resistant (Ministry of Agriculture, Food and Consumer Affairs 1997, see also Sangster 1999, Hugoson and Wallén 2000) and there is the risk of food residues. Thus, the American national organic standards prohibit any use of antibiotics if products are to be labelled as organic (AMS-USDA 2000), while the EU allows a maximum of 'three courses of treatments with chemically-synthesised allopathic veterinary medicinal products or antibiotics' within one year (Council Regulation 1999). This conflict between the wellbeing of the system and that of the individual is a dilemma for organic farming and may be a contributory cause of the criticism about animal welfare in organic systems.

Clearly ecocentric ethics do not offer an obvious focus from which to develop an animal ethics framework for organic farming. However, there are other less radical versions of ecocentric ethics where individuals are also considered to have moral significance. This 'ecocentric pluralism' assigns value both to ecological entities, such as ecosystems and species, and to individual organisms (Stenmark 2002). It can also be argued that ecocentric ethics is based on a fundamental respect for nature and recognises the interconnectedness among all living beings and between them and their environment; hence, animals (as well as humans) are inseparable and important parts of nature and must therefore be treated with care and respect. Consequently, animals can be seen to have moral standing and are more than just a means of production, deserving respect and consideration as important members of the ecological community. For example, some ecocentric philosophers, such as the Norwegian Arne Næss, argue that all living beings are united on a metaphysical level and accordingly, humans will also be harmed if animals are harmed (Næss 1985). Others have argued that domesticated farm and companion animals are an integrated part of the human society, and for this reason they deserve good welfare just as human children do (Callicott 1989). Lund *et al.* (2004a) have suggested that farm animals should be respected as co-workers in the agroecosystem and for this reason they are entitled to good welfare.

Established moral theories such as utilitarian animal ethics and animal rights are inadequate for anchoring animal welfare concerns in organic production systems (Lund *et al.* 2004b). Utilitarianism, so far the dominating paradigm among Anglo-Saxon animal ethicists, considers the suffering, needs and interests of individual animals (Singer 1990), but its one-dimensional focus on consideration of utilities, interests or pleasure is less suitable for farming. Slaughter is not completely prohibited in Singer's utilitarian view, but whether it is permissible depends on how one values the interests of the actors involved. For example, the interest of the gourmet meat eater to consume meat must be weighed against the interests of the animal that is going to be slaughtered. This could be acceptable if, for example, the animal has a fractured leg and faces a long and complicated convalescence that may affect its interest in continuing life, or it could be argued that an animal has no concept of its death and thus does not get its interests violated if it is painlessly and unknowingly slaughtered. Still, it is very difficult to justify commercial farming from a sentientistic utilitarian position.

In addition, organic farming has a different understanding of the individual animal in the moral and ecological order as well as of pleasure, pain and suffering. An ethical position setting the bounds for moral concern at sentient beings does not work well for organic agriculture, which also includes other objects as morally relevant.

Animal rights theories (e.g. Regan 1983) fail as a complementary philosophy for organic animal husbandry since they see the inherent value of sentient animals equal to that of humans. This makes animal agriculture impossible (Fraser 1999) and according to the proponents, all forms of animal agriculture should be abolished (Regan 1983). Thus, these two models of well known and frequently used animal ethics theories do not help organic farming to find an animal ethics that can give guidance on how organic animals should be handled.

To conclude, the answer to the question of whether animal welfare should be a concern for organic farming must be yes. Animal welfare concerns have been an integral part of organic farming from the beginning and can be defended within values espoused by ecocentric ethics.

The organic understanding of animal welfare

The scientific-philosophical debate regarding what animal welfare really is has resulted in three (partly overlapping) categories of definitions (Duncan and Fraser 1997):

1 The *subjective experience approach* argues that the welfare of the animal depends on how the animal experiences its situation; that is, what matters is its subjective feelings like pleasure, pain or fear (e.g. Sandøe and Simonsen 1992, Duncan 1993).
2 The *biological functioning approach* emphasises the animal's biological function, therefore welfare, can be measured through traits such as health, production and reproduction. Satisfactory performance of these functions implies that the animal has good welfare. In one of the most widely used welfare definitions, 'coping successfully with the environment' is included along with biological functioning (Broom 1991).
3 The *natural living approach* proposes that an animal's welfare depends on its capacity to perform a natural behaviour and living a 'natural' life in accordance with its genetically encoded nature or 'telos' as suggested by Rollin (1993). Bernhard Rollin writes (p. 48): 'Not only will welfare mean control of pain and suffering, it will also entail nurturing and fulfilment of the animals' natures.'

The third category is possibly in best accordance with organic values. Not only is natural behaviour important, but also food adapted to animal physiology and an environment similar to the biotope natural to the species are considered important. Studies of organic farmers suggest that they understand animal welfare primarily in terms of 'natural living' (Lund *et al.* 2002, 2004b).

In the organic view, natural living is assigned a value in itself, and the fulfilment of the animals' natures ranks higher than the absence of pain and suffering. Natural living is considered not only as an instrument but also to have inherent value. As an instrumental value, it would be preferred only in as much as it would make the animal feel better or become healthier. Allowing animals a natural life is considered positive in itself, so that some negative experiences for the individual may be tolerated to achieve the positive. To an extent, negative experiences are perceived as a natural part of life that can never be completely removed from an individual animal's spectrum of experiences (Alrøe *et al.* 2001, Lund and Röcklinsberg 2001, Lund *et al.* 2004b). This does not imply that such experiences are not negative for the individual as they happen, but rather that they are an important part of the functional feedback system connecting individual behaviour and the surrounding world (Lund 2002). This approach is also discussed by Vaarst *et al.* (2000), who argue that although 'a natural life' does not guarantee the absence of pain, frustration and discomfort, contact with nature may add certain favourable qualities to the life of an animal, the implications of which are not always measurable. Vaarst *et al.* (2000) prefer to talk about 'valuable experience' and 'a good life' rather than animal welfare:

> A valuable experience may (but not necessarily) contain elements that seem to have a short-term negative impact on the individual, but it nevertheless makes the individual learn something that is of longer term value.

If this approach is further developed, different kinds of negative experiences may be valued differently. For example, many of the welfare challenges in contemporary farming occur either

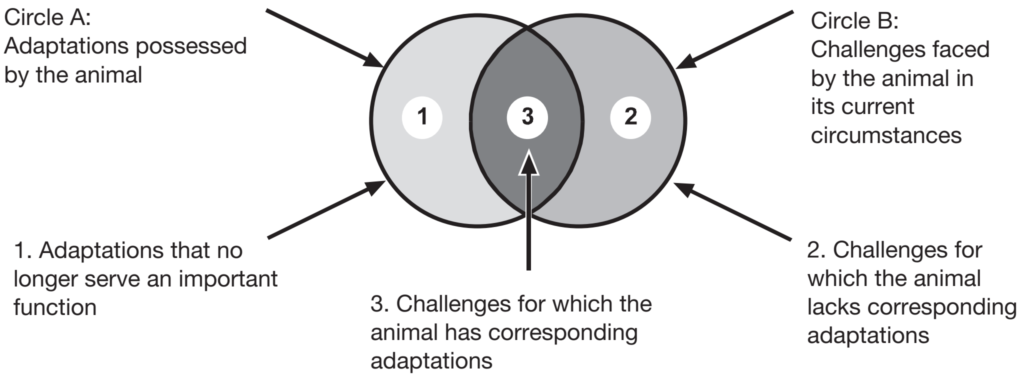

Figure 8.2 Many of the welfare challenges in contemporary farming occur either because the animal has an adaptation that no longer can find a function in modern rearing systems or because the animal lacks adaptations to such systems (after Fraser *et al.* 1997).

because the animal has an adaptation that can no longer find a function in modern rearing systems or because the animal lacks adaptations to such systems (Fraser *et al.* 1997, Figure 8.2). Thus, the stress caused because the animal lacks adaptive strategies to handle the situation (e.g. a noisy fan in the pig house) may be considered worse than the stress outdoor pigs experience with the fox sneaking around their paddock, since animals in the wild are primed to deal with unpredictable conditions, of which predators are an important part. This should by no means stop farmers from protecting their piglets from foxes (albeit by other means than by eradicating the fox population, since the means used must comply with the ecocentric framework). However, the pigs would have to live with the possibility of being exposed to this kind of stress, which should not be the case with the noisy fan. It could, of course, be questioned whether it would be a valuable experience for the pigs, in the sense discussed by Vaarst *et al.* (2000), but it would expose the animals to a wider range of experiences, and add 'excitements' that would still be within their genetic adaptation. Thus, in Figure 8.2 the fan would represent a 'type 2 challenge', whereas the fox would be a 'type 3 challenge'.

The ecocentric philosopher Holmes Rolston (1988) suggested handling the dilemma of animal suffering through applying 'a homologous principle' in animal husbandry: 'Do not cause inordinate suffering, beyond those orders of nature from which the animals were taken. […] Culturally imposed suffering must be comparable to ecologically functional suffering.'

The same view can be found in the organic farming movement (Lund 1996). The organic understanding of animal welfare differs somewhat from that commonly used in conventional farming, where the biological functioning approach is usually seen as the norm. Researchers also prefer the latter approach, since it makes it comparatively easy to quantify welfare states.

Therefore to some extent, the criticism of animal welfare in organic farming may stem from a different understanding of what welfare is. While organic farmers may believe their chickens have good welfare because they have a (relatively) free life in an environment that allows them to perform most of their natural behaviours, the conventional farmer or scientist may focus on the risk of parasite infections, predator attacks, cannibalism and the home-grown feed with low content of certain essential amino acids. From their point of view, the welfare of these animals is being compromised.

Is there a general welfare problem in organic production systems?

Several issues must be considered when trying to answer the question of whether there is a general animal welfare problem in organic production systems. The first one is the issue of what 'good quality of life' should imply for animals. Since there is no 'right' definition, it is necessary to be explicit in how the concept is defined for each individual case.

A second issue is that any production system has its weaknesses and its strengths, such as revealed in the introductory example with the two dog owners and their dogs mentioned earlier. In organic farming, many of the problems stemming from intensive production and crowded conditions are absent or at least less frequent. Problems of abnormal animal behaviours (e.g. tail biting in pigs), extreme production targets, or feeding regimens not adapted to the biology of the animals are less likely to be found, as are 'production' diseases such as respiratory diseases associated with crowding and housing (see also Sundrum 2001). Instead, problems are connected with less disease control (e.g. parasite infections in outdoor production) and the creation of greater risks associated with allowing the animals a more natural and less restricted life. Different attitudes and strategies for management and feeding among organic farmers may also result in other types of welfare problems in organic systems compared to conventional systems.

Third, organic animal husbandry does not have a long tradition and is therefore still being developed, with research efforts needed to identify and improve practices that may cater to the welfare needs of individual animals. It also takes time to 'convert' the thinking of (previously conventional) farmers to develop the skills necessary to manage a production system such as organic farming that is reliant on biological and ecological services to achieve production objectives. Therefore, not only the current situation is of interest, but also the welfare potential of organic systems should be considered. The organic standards have a substantial welfare potential. For example, they are generally more far-reaching and detailed than the animal welfare legislation in many countries, including requirements regarding environment enrichment and access to pasture. It can be argued that animals that live in stimulating environments (that usually applies to free-range conditions) where they can behave naturally are more likely to have better welfare than animals kept in barren environments. Organic standards often restrict or ban mutilations such as tail docking, castration and beak trimming, and several certifying organisations (including the EU regulations) also require humane treatment during transport and slaughter.

Dilemmas

There are welfare dilemmas that organic farming needs to address. The conflict between system wellbeing and individual welfare has already been discussed. Another dilemma caused by the ecocentric approach (and another reason why animal welfare in organic farming has been criticised) is the conflict between the natural living principles versus individual welfare interpreted in terms of 'prevention of suffering' or 'promotion of health'. The high value placed on natural living by organic producers implies that a more natural (and thus less controlled) environment is preferred to a well-controlled environment where the animal is protected from dangers but is less able to have a 'natural' life. Thus, organic systems stipulate free-range systems for poultry even though outbreaks of feather pecking or cannibalism can cause considerable damage in such systems (Bilcik and Keeling 1999). Organic poultry production was criticised in the mid-1990s by the Danish Ethical Council, who identified mortality figures in organic systems as being twice those of conventional poultry herds (Danish Ethical Council Concerning Animals 1995). However at the same time, risk of cannibalism outbreaks can be reduced by inclusion of management options such as provision of foraging opportunities in free-range systems (e.g. Wechsler and Huber-Eicher 1998). Further examples of this dilemma are the preference for natural mating, although artificial insemination programs are superior with regard to disease resistance and elimination of deformities, and the principle of outdoor grazing is favoured in spite of higher risks for parasitic diseases such as *Coccidiosis* and *Ascarid* infections in poultry, piroplasmosis in cattle, and trichinosis and *Erysipelas* infections in pigs.

A further dilemma is that of organic animal welfare and food safety, since outdoor rearing also increases the likelihood of problems with zoonotic parasites such as *Salmonella* and *Campylobacter*. These are not welfare problems for the animals, but may cause health problems for humans who eat animal products.

Improved management, breeding and system development can overcome many of the problems connected with natural living, and while these problems reflect differences in underlying value systems it is important for the organic movement to recognise that natural living and organic feed of themselves are not enough to guarantee the welfare of the individual animal.

Welfare effects of organic feed

The organic requirement to feed roughage to all species is generally beneficial for the animals. This is particularly true for ruminants and also for pigs and poultry, for which it functions as 'behavioural therapy' and provides a fibre supplement in the diet, stimulating digestion. Roughage in pig diets can decrease the risk of infection with detrimental bacteria such as dysentery (*Shigella* spp.), but it may also increase the occurrence of certain parasites (nematodes) (Petkevicius *et al*. 1999).

There have been concerns that the lower intensity feeding due to limited concentrate feeding would result in diseases such as milk fever in dairy cows. However, these worries have not been confirmed. On the contrary, organic dairy cows appear to have fewer problems with metabolic diseases than conventional cows (Lund and Algers 2003). In poultry, there is a problem of how to provide high-producing poultry with enough methionine and to some extent lysine (to growing animals), particularly in regions where the climate prohibits soybean growth. The problem has arisen as both IFOAM and EU standards have banned synthetic amino acids in the feed and have limited the use of products of animal origin (naturally part of poultry diets), and are moving towards requiring 100% organic feed. Whether feed enrichment with synthetic amino acids (corresponding to adding vitamins to the feed) is the best solution to the problem is a debateable and complex issue that cannot be fully discussed here. From a welfare perspective, it appears an acceptable solution, considering that the alternative is usually either deficiency or overfeeding with protein. In particular, the first option imposes considerable stress on the animal and increases the risk of feather pecking (e.g. Wahlström *et al*. 1998).

In some countries (particularly those where organic farms are relatively few) only limited amounts of organic feed are available. This may create welfare problems, since it becomes difficult and expensive for farmers to supplement poor harvests with purchased feed. The alternative, to buy conventional feed, is also expensive since the animals then must go through a new conversion period before the products can be sold as organic.

Research results regarding welfare in organic systems

There is limited scientific knowledge about animal welfare in organic herds. The few published studies deal with health only and not welfare in general. Most of the published studies are concerned with dairy production, rather than more intensive productions systems of pigs and poultry, where the differences between organic and conventional systems are greatest. Generally, these studies indicate that animal health in organic herds is the same as or better than in conventional herds, except for parasite-related diseases, which are more frequent in organic farming (Lund and Algers 2003). This suggests that the criticism of organic farming and problems related to parasite infections may be justified. Apparently the control of internal as well as external parasites is an area where organic farming has not yet managed to develop good alternatives to conventional treatments. The animal welfare effects of these parasitic infestations, at least for pigs and poultry (S.M. Thamsborg, pers. comm., 2005), are difficult to judge, but parasite infestation must be regarded as a risk factor for animal welfare, even when no symptoms are apparent.

Although omitted antibiotic treatment is often mentioned by veterinarians as a problem, it does not appear as higher somatic cell counts or incidences of mastitis (e.g. Vaarst and Bennedsgaard 2001, Hamilton *et al.* 2002). Other methods seem to be applied instead, and antibiotic treatment is still used for the severe cases. Thus, this problem may be overestimated, although practices differ among countries.

Overall, it appears that organic farming does not have a general welfare problem, but rather provides an opportunity to improve welfare if the correct management systems are used. However, there are certain areas or dilemmas that need to be addressed.

Organic farming and the traditional animal protection movements

The animal protection movements and organic farming movements have different backgrounds and history. While the former traditionally focus on the welfare of individual animals and animal experimentation, most of the welfare concerns of the early 'alternative' agriculture movements focused on the negative effects of industrialised animal production. Just as the book *Silent Spring* (Carson 1962) became an environmental alarm clock, *Animal Machines* (Harrison 1964) had similar effects regarding livestock production. These publications contributed to the interest in alternative ways to practice agriculture that grew during the late 1960s, mainly out of an interest in environmental issues and a wish to create an alternative livelihood. While most animal protection movements have grown out of a concern for the welfare of the individual animal, the organic movement has considered animal welfare in relation to the agroecosystem of which the animals are part. In an interview study, organic pioneers saw welfare as a spin-off effect of a well-functioning system (Lund *et al.* 2003). This attitude was confirmed in a questionnaire study, where the concept of natural living came out as much more central to organic farmers than concepts heralded by animal protection movements, such as 'rights', 'dignity' and 'intrinsic value' (Lund *et al.* 2004).

However, as the awareness and knowledge of farm animal welfare has grown, cooperation between traditional animal welfare organisations and organic organisations has increased. Today there exist joint certification programs, for example in Canada (Stoneman and Mowbray 2002) and in the German-speaking countries in Europe (H.-G. Kessler pers. comm. 2005), and the Humane Society of the United States have a section for Farm Animals and Sustainable Agriculture.

Future research needs

Animal welfare is important to organic farmers, to consumers of organic products and not least to organic animals, and thus it is important to be able to guarantee the welfare of organically produced animals, but further research on such production systems is needed.

The differences in understanding of the animal welfare concept compared to conventional systems need further clarification so that indicators of welfare suitable for organic production systems can be developed. Such indicators will make it possible for the certifying organisations to measure and also to communicate the welfare status of organic farms to the consumers. For the farmers it will be an aid in evaluating whether they reach the goals of organic farming.

Research is also needed to solve the welfare dilemmas organic farming is facing. This will involve addressing welfare problems connected to the lack of control and the freedom of natural living. These studies will include issues such as how to avoid parasite infections, feather pecking and cannibalism in poultry, and piglet mortality in outdoor systems. Another crucial research area is how to handle the risk of spreading zoonotic diseases through organic production systems. Further, the dilemma of system versus individual welfare must be solved; for example, through studies addressing alternative treatments to the use of medication like antibiotics and anthelmintics (i.e. preventive health and welfare). The need to develop research in this field is by no means unique to organic farming, but since the latter relies on biological solutions and less control, greater difficulties have to be confronted. Thus, preventive measures become crucial. Since medication may imply that products cannot be sold as organic, alternatives to such medication could have large economic consequences. Research needs in relation to animal health and welfare in organic production have been addressed in the final report of the Network for Animal Health and Welfare in Organic Agriculture (NAHWOA 2002).

Organic farming developed as a response to the dilemmas faced by conventional agriculture, finding solutions transcending the context and creating new perspectives (Christensen 1998). This innovative approach and creativity continues to be required to create 'win–win' situations beneficial both to the system and the individual animal. The challenge for organic farming is to develop husbandry systems where animal welfare is an integrated and positive part of the system and not seen as a problem to be solved; that is, systems where animals contribute with products or services through their natural living (Lund and Weary 2004).

Conclusions

It is important not only to base statements regarding animal welfare on scientific research, but also to be explicit as to how the concept of animal welfare is defined. This will make the discussion of criticism and general issues more constructive. In organic farming, animal welfare is placed in a larger, 'systemic' perspective, and a natural life is usually seen as a precondition for good welfare. However, the dilemma that natural living does not automatically imply welfare for the individual animal must be recognised, just as feeding organic feed does not necessarily contribute to improved quality of life. The limited research available does not indicate that organic animals have worse health or welfare compared to animals in conventional systems. Rather, there is a substantial potential for improved welfare in organic farming systems. However, each production system faces particular challenges, and organic farming must be observant and deal with the challenges linked to organic production (Hovi *et al*. 2003, Lund and Algers 2003). Problems and risks related to the lower control of the animal's environment such as 'parasite-related diseases' is one such area.

Organic farming must be able to guarantee the welfare of organic animals both in theory and in practice. This is necessary, considering the wellbeing of the animals as well as the expectations and requirements of animal welfare in modern society. It is necessary to develop systems where the health and welfare of the individual animal is safeguarded, even though system sustainability is an overall goal, and where natural living coincides with welfare experienced by each individual animal.

References

Alrøe, H.F., Vaarst, M. and Kristensen, E.S. 2001. Does organic farming face distinctive livestock welfare issues? – A conceptual analysis. *Journal of Agricultural and Environmental Ethics* 14: 275–299.

AMS–USDA. 2000. *National Organic Programme: Final Rule*. Agricultural Marketing Service Department of Agriculture. 7 CFR Part 205. Federal Register, December 21, 2000, 80548-80684. Agricultural Marketing Service, United States Department of Agriculture, Washington DC.

Balfour, E. 1943. *The Living Soil*. Faber and Faber, London.

Bilcik, B. and Keeling, L.J. 1999. Changes in feather condition in relation to feather pecking and aggressive behaviour in laying hens. *British Poultry Science* 40: 444–451.

Boehncke, E. 1997. Preventive strategies as a health resource for organic farming. In: Isart, J. and Llerena, J.J. (eds) *Resource Use in Organic Farming. Proceedings of the 3rd ENOF Workshop Ancona Italy June 5–6*. LEAAM-Agroecologica (CID-CSIC), Barcelona pp. 25–35.

Broom, D.M. 1991. Animal welfare: concepts and measurement. *Journal of Animal Science* 69: 4167–4175.

Brown, K. 2004. *A Market-Place Perspective*. Paper presented at the OIE Global Conference on Animal Welfare, Paris 24–25 February 2004. Office for Official Publication of the European Communities, Luxembourg.

Callicott, J.B. 1989. *In Defense of the Land Ethic*. State University of New York Press, Albany.

Carson, R. 1962. *Silent Spring*. Houghton Mifflin Company, Boston.

Christensen, J. 1998. *Alternativer – natur – landbrug*. [Alternatives – Nature – Agriculture]. Akademisk Forlag, Viborg.

Council Regulation. 1999. Council Regulation (EC) No 1804/1999 of 19 July 1999 supplementing Regulation (EEC) No 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs to include livestock production. *Official Journal* L 222 24/08/1999: 0001-0028.

Danish Ethical Council Concerning Animals 1995. *Udtalelse om økologisk husdyrproduktion*. [Statement Regarding Organic Livestock Production.] Det dyreetiske råd, Ministry of Justice, Copenhagen.

Duncan, I.J.H. 1993. Welfare is to do with what animals feel. *Journal of Agricultural and Environmental Ethics* 6(Suppl. 2): 8–14.

Duncan, I.J.H. and Fraser, D. 1997. Understanding animal welfare. In: Appleby, M.C. and Hughes, B.O. (eds.) *Animal Welfare*. CAB International, Wallingford. pp. 19–31.

EUR-Lex 2003. *Protocol on Protection and Welfare of Animals*. <http://europa.eu.int/eur-lex/en/treaties/selected/livre348.html>, Office for Official Publications of the European Communities, Luxembourg.

Frankena, W. 1963. *Ethics*. Prentice-Hall, New Jersey.

Fraser, D. 1999. Animal ethics and animal welfare science: bridging the two cultures. *Applied Animal Behaviour Science* 65: 171–189.

Fraser D., Weary, D.M., Pajor, E.A. and Milligan, B.N. 1997. A scientific concept of animal welfare that reflects ethical concerns. *Animal Welfare* 6: 187–205.

Hamilton, C., Hansson, I., Ekman, T., Emanuelson, U. and Forslund, K. 2002. Health of cows, calves and young stock on 26 organic dairy herds in Sweden. *The Veterinary Record* 150: 503–508.

Harper, G.C. and Henson, S.J. 2001. *Consumer Concerns about Animal Welfare and the Impact on Food Choice – The Final Report. EU FAIR CT98 3678*. The University of Reading, Reading.

Harrison, R. 1964. *Animal Machines*. Vincent Stuart Publishers, London.

Hovi, M., Sundrum, A. and Thamsborg, S. 2003. Animal health and welfare in organic livestock production in Europe – current state and future challenges. *Livestock Production Science* 80: 41–53.

Hugoson, G. and Wallén, C. (eds.) 2000. Proceedings of the symposium on antibiotic resistance with emphasis on animal–human transfer. *Acta Veterinaria Scandinavica* Suppl. 93.

IFOAM 2000. *IFOAM Basic Standards*. International Federation of Organic Agriculture Movements, Tholey-Theley, Germany

Leopold, A. 1949. *A Sand County Almanac*. Oxford University Press, London.
Lund, V. 1996. Etik och ekonomi i ekologisk djurhållning. [Ethics and Economy in Organic Farming.] *Ekologiskt lantbruk* 20: 102–107.
Lund, V. 2002. *Ethics and Animal Welfare in Organic Animal Husbandry – an Interdisciplinary Approach*. PhD thesis. Acta Universitatis Agriculturae Sueciae Veterinaria 137. Department of Animal Environment and Health, Swedish University of Agricultural Sciences, Skara.
Lund, V. and Algers, B. 2003. Research on animal health and welfare in organic farming – a literature review. *Livestock Production Science* 80: 55–68.
Lund, V. and Röcklinsberg, H. 2001. Outlining a conception of animal welfare for organic farming systems. *Journal of Agricultural and Environmental Ethics* 14: 391–424.
Lund, V., Hemlin, S. and Lockeretz, W. 2002. Organic livestock production as viewed by Swedish farmers and organic initiators. *Agriculture and Human Values* 19(3): 255–268.
Lund, V., Anthony, R. and Röcklinsberg, H. 2004a. The ethical contract as a tool in organic animal husbandry. *Journal of Agricultural and Environmental Ethics* 17(1): 23–49.
Lund, V., Hemlin, S. and White, J. 2004b. Natural behaviour, animal rights or making money – a study of Swedish organic farmers' view of animal issues. *Journal of Agricultural and Environmental Ethics* 17: 157–179.
Lund, V. and Weary, D. 2004. Understanding animal behaviour and its use in organic animal husbandry. In: Vaarst, M., Roderick, S., Lund, V. and Lockeretz, W. (eds) *Animal Health and Welfare in Organic Agriculture*. CABI Publishing, Wallingford. pp. 95–116.
Magnusson, M., Arvola, A. and Koivisto Hursti, U.-K. 2001. Attitudes towards organic foods among Swedish consumers. *British Food Journal* 103(3): 209–226.
Ministry of Agriculture, Food and Consumer Affairs 1997. *Antimicrobial Feed Additives. Report from the Commission on Antimicrobial Feed Additives*. Government Official Reports, Ministry of Agriculture, Food and Consumer Affairs, Stockholm.
NAHWOA 2002. *Final Recommendations and Comments. Summary*. Network for Animal Health and Welfare in Organic Agriculture. <http://www.veeru.reading.ac.uk/organic/NAHWOAConclusionsFinal.pdf>.
Niggli, U. and Lockeretz, W. 1996. Development of research in organic agriculture. In: Østergaard, T.V. (ed.) *Fundamentals of Organic Agriculture. Proceedings Vol. 1 11th IFOAM International Scientific Conference 11–15 August Copenhagen*. pp. 9–23. IFOAM, Bonn.
Næss, A. 1985. Identification as a source of deep ecological attitudes. In: Tobias, M. (ed.) *Deep Ecology*. Avanti Books, San Diego. pp. 256–270.
Petkevicius, S., Nansen, P., Knudsen, K.E.B. and Skjøth, F. 1999. The effect of increasing levels of insoluble dietary fibre on the establishment and persistence of *Oesophagostomum dentatum* in pigs. *Parasite* 6: 17–26.
Roderick, S. and Hovi, M. 1999. *Animal Health and Welfare in Organic Livestock Systems: Identification of Constraints and Priorities. Report to the Ministry of Agriculture Fisheries and Food*. VEERU, Department of Agriculture, University of Reading, Reading.
Rollin, B.E. 1993. Animal welfare, science and value. *Journal of Agricultural and Environmental Ethics* 6 (Suppl. 2): 44–50.
Rolston, H. 1988. *Environmental Ethics. Duties to and Values in the Natural World*. Temple University Press, Philadelphia.
Röcklinsberg, H. 2001. *Das seufzende Schwein. Zur Theorie und Praxis in Deutschen Modellen zur Tierethik*. PhD thesis. Harald Fischer Verlag, Erlangen.
Sandøe, P. 1999. Quality of life: three competing views. *Ethical Theory and Moral Practice* 2: 11–23.
Sandøe, P. and Simonsen, H.B. 1992. Assessing animal welfare: Where does science end and philosophy begin? *Animal Welfare* 1: 257–267.

Sangster, N.C. 1999. Anthelmintic resistance: past, present and future. *International Journal for Parasitology* 29: 115–124.

Singer, P. 1981. *The Expanding Circle: Ethics and Sociobiology*. Farrar, Straus and Giroux, New York.

Steiner, R. 1929. *Landwirtschaftlicher Kursus*. Section for Natural Science of the Anthroposophic Society, Dornach.

Stenmark, M. 2002. *Environmental Ethics and Policy Making*. Ashgate Aldershot, Burlington.

Stoneman, A.B. and Mowbray, L. 2002. Humane labeling programmes: can they work with organic certification programmes? In: Thompson, R. (ed.) *Cultivating Communities. Proceedings of the 14th IFOAM Organic World Congress, 21–24 August, Victoria, Canada*. p. 74. International Federation of Organic Agriculture Movements, Bonn.

Sundrum, A. 2001. Organic livestock farming. A critical review. *Livestock Production Science* 67: 207–215.

Tannenbaum, J. 1991. Ethics and animal welfare: The inextricable connection. *Journal of the American Veterinary Medical Association* 198: 1360–1376.

Vaarst, M. and Bennedsgaard, T.W. 2001. Reduced medication in organic farming with emphasis on organic dairy production. *Acta Veterinaria Scandinavica* 42(Suppl. 95): 51–57.

Vaarst, M., Roepstorff, A., Feenestra, A., Høgedal, P., Larsen, V.A., Lauritsen, H.B. and Hermansen, J.E. 2000. Animal health and welfare aspects in organic pig production. In: Hermansen, J.E., Lund, V. and Thuen, E. (eds) *Ecological Animal Husbandry in the Nordic Countries*. *Proceedings, NJF-seminar 303*. Danish Research Centre for Organic Farming, Tjele. pp. 177–178.

Verhoog, H., Lund, V. and Alrøe, H. 2004. Animal welfare, ethics and organic farming. In: Vaarst, M., Roderick, S., Lund, V. and Lockeretz, W. (eds) *Animal Health and Welfare in Organic Agriculture*. CABI Publishing, Wallingford. pp. 73–94.

Wahlström, A., Tauson, R. and Elwinger, K. 1998. Effects on plumage condition, health and mortality of dietary oats/wheat rations to three hybrids of laying hens in different housing systems. *Acta Agriculturae Scandinavica Section A, Animal Science* 48: 250–259.

Wechsler, B. and Huber-Eicher, B. 1998. The effect of foraging material and perch height on feather pecking and feather damage in laying hens. *Applied Animal Behaviour Science* 58: 131–141.

Chapter 9

Organic standards and certification

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Introduction

Paradoxically, the regulatory systems that were developed to protect the integrity of organic agriculture including standards setting and conformity assessment systems are now reshaping the organic landscape in ways that threaten many of the values held by the movement that created it. Organic standards and certification systems have had key roles in clarifying, harmonising and ensuring the integrity of organic agriculture as it moves from movement-driven agricultural niches to mainstream markets worldwide. However, with the growth of organic markets reaching US$25 billion (Rundgren 2004), governments have become increasingly involved in organic regulation, resulting in a loss of ownership of the meaning of organic agriculture by the movement itself. Increased international trade of organic products has resulted in complex organic regulatory systems fraught with duplication and overlaps among the various government regimes and the private regulatory system. Such bureaucratisation of organic agriculture is creating barriers to trade, particularly for small-scale producers in developing countries (Harris *et al*. 2001, Parrott and Marsden 2002, Raynolds 2004).

This chapter outlines the history of the development of organic regulatory structures, provides a snapshot of the current situation with respect to organic standards setting and conformity assessment activities, and discusses three key regulatory challenges facing organic agriculture. These include the tensions between the private systems dominated by the International Federation of Organic Agriculture Movements (IFOAM) and public systems managed by various national and regional governments, difficulties in balancing producer realities on the ground and consumer requirements for a clear understanding of what organic agriculture means worldwide, and the increasing over-regulation of organic agricultural production and trade that may inadvertently squeeze out key stakeholders at the heart of the organic movement: smallholder farmers. In outlining tentative steps towards addressing these challenges, the chapter briefly sketches possible pathways for harmonisation among organic regulatory systems, suggests possibilities for balancing local and global needs through incorporating flexibility into standards-setting processes based on examples from IFOAM processes, and outlines two promising developments for organic smallholder producers:

1 the development and increasing acceptance of internal control systems as a tool for inspection and certification; and
2 a new stage in the evolution of organic assurance, the development of participatory guarantee systems for local markets.

History of the development of organic standards and certification

Organic agriculture developed as an alternative form of farming system compatible with natural systems whose origins can be traced back to the work of Rudolf Steiner and Sir Albert Howard in the 1920s (Geier 1997). As organic agriculture grew into the 1950s and 1960s, the first informal regulatory tools were developed including loosely developed codes of conduct and informal inspections (Swedish National Board of Trade 2003). At that time, organic agriculture was very much outside the mainstream of agrifood business, when according to one prominent organic trader, 'nobody took us very seriously' (Segger 1997). This brought the various stakeholders in the organic movement together, leading to the development of the IFOAM in 1972. During the 1960s and 1970s, pioneering farmers' organisations actively involved in organic farming and extension work began to feel the need to define more precisely what organic farming meant in order to give guidance to new groups who had recently joined (Bowen 2002). Processes to develop organic standards ensued, leading to the first *IFOAM Basic Standards for Organic Agriculture* in 1980 (IFOAM 1980). These standards have since undergone many revisions.

Parallel to the formalisation of organic principles and practices into standards, the regulatory mechanisms by which the organic movement verifies that farmers and processors comply with organic standards have also become much more concretised. As organic markets developed beyond local communities in which farmers and consumers knew each other, consumers began to ask for an independent guarantee of compliance to organic principles and methods. To meet this need, the organic movement grew to encompass private certification bodies, the first of which developed from organic farmers' associations (Courville 2001, Bowen 2002). Over time, more certification bodies developed to meet market demand.

In the mid 1980s, members concerned about the future development of organic trade began asking IFOAM to evaluate the performance of these certification bodies as a vehicle for enhancing mutual trust, leading to cooperation (Commins 2002). In 1992, the development of the IFOAM Accreditation program was approved by the General Assembly. This program began accepting applications for accreditations by organic certification bodies in 1993. In 1997, after years of discussion about the need to establish a separate legal entity to operate the IFOAM Accreditation program, the International Organic Accreditation Service (IOAS) was established (Commins 2002). By December 2004, there were 32 IFOAM accredited certification bodies operating in over 70 countries, with another two applications under consideration (IOAS 2004b).

The private system in place to regulate organic agriculture represents one of the largest and most established global, non-government systems of regulation of industry production, processing and commodity trading. However, as the worldwide volume and value of organic production has increased, governments have increasingly taken an interest in regulating the organic industry. Although not the first government entity to regulate the organic industry as the United States of America (USA) States Oregon and California adopted organic legislation by the 1970s, with governments in France, Spain and Denmark adopting regulations prior to the EEC 2092/91 regulation (Bowen 2002; 3), the European Economic Community Council Regulation 2092/91 introduced in 1991 had a major role in shaping the future of organic regulatory regimes. This was followed by the development of regulations in the USA, Canada and Japan among other countries. Governments worldwide have now developed, or are in the process of developing, organic regulations that outline definitions of organic agriculture and processing, as well as establishing processes by which organic certification bodies are approved to operate within their jurisdiction. Unfortunately, this has created significant problems for the international trade of organic products as a result of lack of coordination between governmental authorities in terms of processes of mutual recognition and equivalency. The picture is further complicated by the lack of integration between the private regulatory framework operated by the IOAS and IFOAM, and the many national or regional governmental regulatory regimes.

Organic standards and standards setting processes

As of 2003, of the 364 bodies identified by a survey of the newsletter *The Organic Standard* that offered organic certification, 65 stated that they had developed their own standards (Commins 2003). In the same year, 60 countries were involved in developing organic regulations including 37 countries that had fully implemented regulations for organic agriculture (15 EU countries; 11 in the rest of Europe – Cyprus, Czech Republic, Hungary, Iceland, Lithuania, Norway, Poland, Slovak Republic, Slovenia, Switzerland, Turkey; seven in the Asia-Pacific – Australia, India, Japan, Philippines, South Korea, Taiwan, Thailand; Argentina; and Costa Rica, the USA, Tunisia) with an additional eight countries with final regulations approved but without full implementation (i.e. had certification mechanisms in place: Croatia, Estonia, Malaysia, Brazil, Chile, Guatemala, Mexico, Egypt) and a further 15 countries in the process of drafting regulations (Albania, Georgia, Romania, Yugoslavia, China, Hong Kong, Indonesia, Canada, Nicaragua, Peru, St Lucia, Madagascar, South Africa, Israel, Lebanon) (Commins 2003). When adding the two international standards to these figures, the *IFOAM Basic Standards* (IBS) and the Codex Guidelines, one begins to have an idea of the complexities involved in defining the meaning of organic agriculture.

In examining the organic standards internationally, it is useful to take a chronological approach, as more recent standards and regulations are generally heavily influenced by earlier ones. As was mentioned above, the first wave of standards setting was undertaken by farmers' associations, the first of which was published by the Soil Association in the United Kingdom (UK) in 1967 (Commins 2003). These were key references for the initial development of IBS that were in turn influential in the drafting of European Union (EU) EEC Regulation 2092/91 in 2001 (Commins 2003). Codex Guidelines as well as most other organic regulations were then heavily influenced by the European regulation, partly because the importance of the EU market and because other governments were eager to facilitate trade with the EU. As the biggest markets for organic products are in Europe, the USA and Japan, most other governments have developed systems to ensure compliance or equivalence with their regulations.

As was mentioned above, IFOAM first published its *Basic Standards* in 1980 as a way to harmonise the meaning of organic across an increasingly globalised movement. The IBS have now been translated into 20 languages (IFOAM 2004). The IBS are revised periodically by its membership that includes about 700 organisations in over 100 countries, representing producers, producer organisations, non-governmental organisations, traders, retailers, consumers and researchers, among others. Any organisation with a primary interest in organic agriculture can become a member with full voting rights; those with some degree of interest and activities can become associates. Up until 2002, IBS were revised at the General Assembly, the federations' highest decision-making body. However, at that time, it was decided to separate standards revision processes from the General Assembly to allow more time for discussion on strategic directions for the movement, and to improve access to standards participation through electronic and postal means by members who would not be able to travel to attend the General Assembly. A norms management committee oversees the work of standards committee and the committee responsible for the revision of IFOAM Accreditation criteria. To support this work and ensure transparent processes, IFOAM has developed policies for the revision of

IBS and for guidance in any new standard development or addition to an existing standard (ISEAL Alliance 2004b).

As a non-governmental organisation, IFOAM is continually searching for ways to demonstrate legitimacy and credibility that are generally taken for granted in governmental systems. In terms of standards-setting processes, IFOAM is a member of the International Social and Environmental Accreditation and Labelling (ISEAL) Alliance and as such, is required to implement the ISEAL Code of Good Practice for Setting Social and Environmental Standards that was officially launched in April 2004. The Code includes procedural requirements such as the inclusion of a complaints resolution mechanism, periods for comment, the publication of a work program, the need to take into account comments received through at least two rounds of comment submissions by interested parties, prompt publication of standards and periodic revision. The Code also includes requirements for effectiveness, relevance and international harmonisation as well as participation in the standards development process including the need to proactively seek contributions from interested parties, paying particular attention to the needs of disadvantaged groups such as developing countries and small and medium-sized enterprises (ISEAL Alliance 2004a). Through such tools, ISEAL membership provides additional assurance of the integrity of the IFOAM standards setting processes to key stakeholders, particularly government agencies.

The IBS are standards for standards, in that accredited certification bodies are required to use them as the basis for their own certification standards. The IBS are divided into general principles, standards that require compliance and recommendations. Over time, with experience in implementation, recommendations may be upgraded to standards. As such, there is an inbuilt mechanism for incorporation of new learning.

The other internationally recognised standard is the Codex Guidelines. The Codex Alimentarius Commission was created in 1961 by its two parent organisations, the Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO). As an intergovernmental body, only member governments that have decision-making powers though international organisations may participate as observers (Vaupel 2001). In 1999, Codex adopted Guidelines for the Production, Processing, Labelling and Marketing of Organically Produced Foods with additional sections concerning livestock and livestock products as well as beekeeping and bee products adopted in 2001. In accordance with general Codex objectives, these guidelines were to facilitate the harmonisation of organic standards at the international level and prevent misleading claims, as well as ensuring fair trade practices (Commins 2003).

As regards government regulations, the EEC Council Regulation 2092/91 on Organic Agriculture was first introduced in 1991, followed by the Japanese Agricultural Standard of Organic Agricultural Products (JAS) in 2000. After receiving almost 300,000 mainly negative public comments on its draft rule released in 2000, the National Organic Program Rule CFR Part 205 of the US Department of Agriculture was finally approved in 2002 with substantial revisions (Grolink 2002). Several other government regulations have since been developed or are in the drafting stages, most of which are based on international standards and the regulations of those countries with key organic markets.

Conformity assessment processes (international verification processes)

As with organic standards, there are significant overlaps between the private accreditation program run by the IOAS using IBS and government conformity assessment systems. Given the lack of a multilateral system for organic regulation among governments and a lack of coordination between governments and the private regulatory system, the international trade of organic products has indeed become a nightmare. This section outlines particular features of the private accreditation program and the key governmental conformity assessment processes, focusing mainly on the EU system.

IFOAM's accreditation program run by the IOAS is implemented according to the IFOAM's accreditation criteria that are revised periodically. Given that IBS are standards for standards, it is a requirement of IFOAM accredited certification bodies to develop their own standards for certification, based on IBS.

The IFOAM accreditation program has grown from three accredited certification bodies in 1994 to 32 as of December 2004. In addition to IFOAM accreditation, the IOAS also offers International Organization for Standardization ISO Guide 65 accreditation as a way to add value to the services provided to organic certification bodies. Any certification body can apply for IFOAM accreditation, be they private or state-run. One of the newest accredited certification bodies is the Washington State Department of Agriculture Organic Food Program (Commins 2003, IOAS 2004b).

As an international accreditation program, the IFOAM program has been working to ensure mutual recognition among its accredited certification bodies, facilitating international trade and consumer acceptance of organically certified products. In order to strengthen recognition of IFOAM accreditation among traders and consumers, the IFOAM seal was launched in 1999 to be used in conjunction with the logo of accredited certification bodies (Commins 2003). Furthermore, a mutual recognition agreement among IFOAM accredited certification bodies was developed as a way to facilitate acceptance of products certified by one accredited certification body into another market. However, its implementation has been hampered by perceived quality differences among the accredited certification bodies. The trade implications of this lack of coordination are significant, and weaken the appeal of the private international accreditation system as a harmonised regulatory solution.

Given that the IOAS is a non-governmental organisation operating an international accreditation program, it is a rarity in the world of conformity assessment, dominated by the International Accreditation Forum and its members as national accreditation bodies. In order to demonstrate its competence to the largely government-run verification systems, it sought and gained recognition by the United States National Institute of Standards and Technology, a non-regulatory federal agency within the US Commerce Department's Technology Administration in August 2004. This recognition is based on an evaluation of the IOAS against ISO/IED Guide 61 covering accreditation for both IFOAM norms and ISO/IEC 65 (IOAS 2004a).

Unlike the IFOAM accreditation program, government-run conformity assessment systems mainly operate at a national level, with no multilateral arrangements in place to facilitate trade of organically certified products recognised by one country into a second country. This has led to a situation in which a certification body operating in one country needs to obtain accreditation after accreditation to enable the products that it certifies to enter into multiple markets as organic.

As the first fully elaborated regulation, the EU Council Regulation 2092/91 established a conformity assessment system that 'allows for recognition of private certification bodies by a designated authority according to specified criteria'. In establishing their regulations, other countries have generally followed this example with departments of agriculture usually taking on the responsibility of the designated authority (Commins 2003).

A defining aspect of the EU recognition system is that it was developed to be applicable only to EU-based certification bodies. Within the EU, certified organic products that meet the regulations can be freely marketed across all EU countries. For organic products from third countries, additional steps are required. Article 11 (1) and 11 (2) allow for countries to be listed as having rules in compliance with EC Regulations. After comprehensive assessment, such countries can be identified as 'third countries' and certification bodies accredited under their governments' programs can be accepted. As of April 2003, there were only eight countries approved, only two of which were developing countries: Argentina and Costa Rica (Swedish National Board of Trade 2003).

A second option called 'importer derogation' is provided under Article 11 (6) that was introduced as an exception rule when it was realised that the first option would cause significant difficulties and delays for organic trade from third countries. In this scenario, an interested importer files an application to the competent authority in an EU country requesting permission to market the product in the EU as organic. An importer-dependent permit is granted for a limited period of time (i.e. one year) if equivalence to the EU regulation can be proven. This option, which accounts for 90% of imports to the EU, forces producers in developing countries to become highly dependent on importers in the EU and it places significant administrative burdens on importers. Furthermore, there have been significant differences in the application of the import derogation rule among the member states of the EU, creating uncertainty for both exporters and importers (Swedish National Board of Trade 2003).

The third option outlined in Article 11 (7) provides for an exception in which, at the request of a member state of the EU, an individual inspection body in a third country can be approved following an assessment of that inspection body using appropriate means. This does not necessarily require an on-site inspection of the inspection body. However, this option has seen rather limited use, with just one instance up to mid 2003 (Swedish National Board of Trade 2003).

The impact of the EU conformity assessment system has been to encourage third countries to adopt the EU regulation, given that in practice they need to demonstrate compliance in order to obtain third country status (Swedish National Board of Trade 2003). Most other countries have followed the EU example and recognise only domestically based certification, except for the USA and Japan that allow foreign certification bodies to apply directly for recognition.

In addition to direct application by a foreign certification body, the National Organic Program (NOP) rule of the United States Department of Agriculture (USDA) provides two other options for approval of foreign certification bodies. These include accreditation of a foreign certification body by a government whose standards meet the US regulation, and accreditation of a foreign certification body by a government that has negotiated an equivalency agreement with the USDA (Joint Working Party on Trade and Environment 2002).

In the JAS system, products can be labelled as organic if they have been certified by a registered certification organisation in Japan, if they have been certified by a Registered Foreign Certification Organisation (RFCO) in the exporting country through recertification of imports where the organic raw material is certified by a certification body in the export country while the importer is certified by an RFCO in Japan, or through the use of contracted inspection services where registered certification bodies delegate inspections to trusted certification bodies in export countries recognised by their own government or by an internationally reliable system such as the IOAS (Joint Working Party on Trade and Environment 2002). This last option is interesting in that it allows for a bridge between private and governmental systems.

In terms of criteria for the approval of private certification bodies, the EU regulation requires compliance to Annex 3 of the regulation in addition to ISO/IEC Guide 65. Annex 3 contains requirements not included in ISO Guide 65 such as parallel production. This format is similar to the IFOAM system with specific accreditation criteria that are not covered in the ISO guide. The USA and Japan have each developed distinct requirements. Beyond this, some countries such as India and Australia (in draft requirements) have chosen to base their criteria on IFOAMs (Commins 2003).

Key challenges for the future of organic regulation

The rather jumbled picture painted of the organic regulatory landscape in the last two sections raises key challenges facing organic agriculture and trade. These include tensions between private and public regulatory systems and the desperate need for international harmonisation, the challenge of building regulatory systems that ensure consistency in the assurance provided to global consumers while allowing for locally appropriate adaptations, and finally, with increased regulatory burdens caused by the formalisation of organic assurance, the challenge of ensuring continued access by smallholder producers, particularly in developing countries.

One harmonised global organic regulatory system needed

There has been a recent explosion of private and public organic standards and conformity assessment systems. The lack of harmonisation between the private and public systems and among governmental regulatory regimes poses significant threats to the future growth of organic agriculture and trade.

Because certification bodies are required to obtain organic accreditations to meet market demands and regulatory requirements for each import market (not to mention additional accreditations for other market-based requirements), the costs of access to markets through certification continue to rise (Guthman 1998, Harris *et al.* 2001). In order to ensure that a product can be labelled as organic in an import market, government regulations where they exist must be complied with. At the same time, market requirements may dictate the use of the private system, given solidarity and confidence in the organic movement (Harris *et al.* 2001). Even though Costa Rica is one of the few ‘third countries’ under the EU organic regulatory regime, ‘local certification bodies are not recognised in EU markets and farmers are still asked to certify under different European certification bodies, depending on the client’s preferences’ (Echeverría 2004). Retailers are important in expressing certification preferences, as illustrated in the UK retailer Sainsbury’s policy to only accept organic products from IFOAM-accredited certification bodies for its own-label organic products (Sainsbury’s Supermarkets 2005). The lack of effective cooperation between private and public stakeholders results in additional costs and complications.

The costs of compliance and verification are compounded by the increasing comprehensiveness and complexity of organic standards and regulations, as they are revised and ‘improved’ (Harris *et al.* 2001). While organic agriculture is a relatively simple concept, it is now codified in standards and regulations that can take up almost 100 pages of legal and technical text. The Consolidated Text of the European Council Regulation 2092/91 is 94 pages long, and ‘Entire Standards’ of the English language version of the US NOP Rule is 554 pages, including regulatory and additional text. Translating such requirements into something meaningful for smallholder farmers in Northern Uganda or East Timor is indeed a challenge. Given high rates of illiteracy among smallholder producers in developing countries, complex market and regulatory record-keeping requirements create significant compliance burdens (Harris *et al.* 2001, Raynolds 2004). Stories abound that highlight the challenges faced by smallholders, including a report from Mexico where at least ten small producer groups were decertified in 1999 as a result of their inability to manage the paperwork associated with organic certification (Boersma 2000 in Parrott and Marsden 2002).

As the fastest growing segment in the foods sector globally, organic agriculture holds great promise as a development option for many farmers in developing countries, particularly those with a history of low or no use of synthetic chemicals, in countries with low labour costs, among other factors (Soto 2003). At the same time, while there may be comparative advantages for developing countries in organic agriculture exports, within the wider context of international trade in agricultural commodity products, developing countries are placed at a disadvantage. This is as a result of agricultural subsidies of key developed country economies such as the USA and the EU that distort commodity prices and prevent developing countries from making use of their trade advantages in this sector (Martin and Winters 1995, Grant 1997, Pletcher 2005). Declining terms of trade, dependence on a few commodities for export earnings, tariff protection on value-added goods and the increase in transfer pricing in the private sector also disadvantage developing country exports (Ekins *et al.* 1994, Ropke 1994). A further challenge to developing countries is the growing number of voluntary product standards that have the potential to become non-tariff barriers to developing country exports, particularly for smallholder producers. Such barriers include significant information and managerial demands, higher capital requirements and certification costs (Pletcher 2005).

Although organic agriculture can offer significant market opportunities for producers in developing countries, if organic regulation is not managed appropriately, it can raise non-tariff barriers to trade like other product and process standards. For example, developing countries have had to adopt largely foreign organic regulations as their own, with little acknowledgement that agricultural production conditions can vary considerably between regions. Furthermore, government regulatory systems are set up mainly to interface with other government regulatory systems through bilateral recognition of equivalence (or compliance). This places developing country producers and exporters, whose governments do not prioritise developing organic regulatory systems, at a disadvantage in that they will be required to find other, more expensive ways to access import markets (Joint Working Party on Trade and Environment 2002, Swedish National Board of Trade 2003). Such complex regulatory requirements can lead to significant trade losses as highlighted in the following example (Nycander 2000 in Parrott and Marsden 2002):

> In September 1999, the first organic certified Robusta coffee in Uganda was ready for export. But when import clearance in the EU was held up, the customer lost interest. Five months later the two containers were still at the factory in Kampala.

According to Felicia Echeverría, Manager of the National Organic Agriculture Program from the Department of Agriculture and Animal Husbandry in Costa Rica (Echeverría 2004):

> if no changes in the current situation occur in the near future, more and more small organic farmers from developing countries (the thin part of the rope) may drop out of certified organic markets as the price premium is not enough to compensate the difficulties faced to comply.

With respect to international trade law, some interesting issues come into play. According to the Technical Barriers to Trade Agreement (TBT) of the World Trade Organization (WTO), member governments must use international standards where they exist, or the relevant parts of them, as a basis for their technical regulations except when such international standards or relevant parts would be an ineffective or inappropriate means for the fulfilment of the legitimate objectives pursued, for instance because of fundamental climatic or geographical factors or fundamental technological problems (WTO 1994). As the IBS are listed in the ISO Directory of Standards, these are generally considered international standards along with Codex Guidelines. While the IBS have been used informally as baselines for the development of national organic regulations, a formalised process to evaluate and promote harmonisation of organic standards and regulations has been lacking.

Furthermore, the principle of equivalence is encouraged in the TBT with members being required to give positive consideration to accepting as equivalent technical regulations of other members, even if these regulations differ from their own, provided they are satisfied that these regulations adequately fulfil the objectives of their own regulations (WTO 1994). Similar principles are set out for the arena of conformity assessment (Courville and Crucefix 2004). However, it is much easier for a regulatory body to require compliance to its own standards than to try to work out what equivalence would entail with not one, but many third countries. As such, compliance as opposed to equivalence has tended to prevail (Swedish National Board of Trade 2003).

The TBT Agreement Article 2.2 requires that 'technical regulations shall not be prepared, adopted or applied with the view to or with the effect of being "more trade-restrictive than necessary to fulfil a legitimate objective"' (Swedish National Board of Trade 2003). The legitimate objective is indeed the protection of the integrity of organic products. However, given the state of organic regulation characterised as an 'increasingly chaotic system for international trade' by the IFOAM Organic Guarantee System Manager (Bowen 2002), surely the current regulatory arrangements for organic agriculture are more trade-restrictive than necessary if the result is to increase costs, allow for wasteful duplication of resources, and push key constituents of organic agriculture out of the system: smallholder organic farmers.

Fortunately, both private and public regulatory agencies are aware that the current regulatory gridlock is a serious threat to the future of organic agriculture and trade. This has been highlighted through efforts by IFOAM, the United Nations Conference on Trade and Development (UNCTAD) and the FAO in the joint organisation of a conference on International Harmonisation and Equivalence in February 2002 that has continued through the work of the International Task Force on Harmonisation and Equivalence in Organic Agriculture (ITF). A positive sign is that IFOAM and the IOAS, as well as several key governments including the EU, are actively engaged and are committed to finding a solution through these processes. However, concrete steps to move toward harmonisation and equivalence, both between government authorities and between the IOAS and governments, will be slow to develop.

In terms of future directions, IFOAM has been engaged since 1995 in some serious soul-searching to rethink its role in organic standards-setting and conformity assessment given the increasing activities of governments in organic regulation. One direction that has strong grounding in current practice is that the organic movement should continue to work to drive forward improvements and innovation in organic standards setting.

Standards setting is a continually evolving process for both the private and public sectors. As an example, coverage of livestock was originally left out of the initial versions of both the EU and JAS regulations and was subsequently added in later revisions (Commins 2003). The scope of IFOAM's standard setting is broader than the narrower focus of regulatory agencies (e.g. addition of a chapter on social justice since 1996, draft chapters on aquaculture and forestry introduced in the most recent revisions). As new areas of standards-setting are gradually adopted into IBS, partly through private standards developments of its members, it is also plausible to think that such leading edge organic standards-setting will eventually make its way into other organic standards and regulations.

However, given the prioritised need for harmonisation, there are different ways in which IFOAM could be involved in driving forward innovation in organic standards-setting. The IFOAM World Board is proposing a new model with the hope that it will facilitate cooperation and harmonisation with government agencies as well as encourage innovation. IFOAM would register government and private certification standards that meet an IFOAM Basic Norm and that have been developed according to a new Basic Norm for Standard-setting that IFOAM would develop. As outlined in a recent proposal for revising the IFOAM Guarantee System, 'IFOAM will develop and register new certification standards according to existing and emerging needs in organic production and processing worldwide, and will make them publicly available for use' (IFOAM World Board 2005). By creating different levels of standards including a more generic standards norm complemented by more specific standards, the IFOAM World Board is trying to balance the need for simplification and harmonisation of standards while at the same time encouraging innovation in standards-setting. As the details of such a proposal are being developed, it is too early to evaluate the possible results and implications of such a shift.

Regardless of whether the IBS remain as they are or are revised into a generic standards norm complemented by certification standards, there would be a need for some sort of recognition of the IFOAM standards norm by governments. With the support of the TBT Agreement requiring harmonisation to international standards and recognition through the ISO Directory of Standards of IBS as international standards, there is a strong case for government recognition of IFOAM standards. IFOAM is uniquely placed to maintain and revise international organic standards setting, drawing on the expertise and knowledge of its members and other interested parties. IFOAM has demonstrated its ability to do so in a timely and cost-effective way since 1980. Some kind of relationship would need to be developed with the Codex Guidelines as the other recognised international organic standard. What is needed is the political will on the part of national and regional governments to support such a standards-setting regime.

With respect to conformity assessment, even IFOAM acknowledges that 'governments' strength is primarily in the field of enforcement' (Bowen 2002). However, given the overlap between private and public systems with many market participants who are requesting IFOAM accreditation though being bound by law to ensure governmental regulatory compliance, there will be a need to develop new collaborative models of regulation between private and governmental systems as well as among governmental programs. A further component of the IFOAM World Board's proposal for revising its own Guarantee System is for IFOAM to recognise and register government and private supervision bodies whose certification requirements meet an IFOAM Basic Norm for Conducting Organic Certification. The result would be the creation of different types of registers including a register of certification standards as discussed above and a register of recognised supervision bodies. Certification bodies under a recognised supervision body and using a registered standard would be eligible to join the system (IFOAM World Board 2005).

While IFOAM is proposing changes to it own regulatory regime, additional proposals for coordination are arising out of the ITF process. Short-term actions being proposed by the ITF to lay the groundwork for cooperation include the development and acceptance of common definitions, the development of a database system for cross-referencing comparisons of different organic standards and regulations, a comparative analysis of IFOAM Basic Standards and Codex Guidelines, comparison of IFOAM accreditation criteria and ISO Guide 65, comparisons between IFOAM, Codex, EU regulation, USDA NOP and JAS requirements as well as the subsequent development of common regulatory objectives based on these activities (ITF 2004).

It is hoped that these concrete activities will facilitate longer-term harmonisation. Although models of harmonisation and equivalence in operation outside of the organic sector have been presented to the ITF (Courville and Crucefix 2004), a long-term strategic goal that was recently presented included the following components: production standards compliant with one general baseline international standard (using Codex and IBS as building blocks), one harmonised set of certification requirement (using ISO Guide 65 and IFOAM Accreditation criteria as starting points) and one accreditation/approval mechanism for conformity of assessment bodies (or equivalency among the various mechanisms, possibly a hybrid between an international accreditation model and national approval systems). While the establishment of an International Forum for Organic Regulation (IFOR) was suggested to oversee the development of such a regulatory structure, most ITF members were not in favour of creating yet another entity, instead preferring to work through existing institutions (ITF 2005).

Movement towards any harmonised organic regulatory system will require several small but concrete steps that will enable competency assessments and trust building among the various parties. Although urgent action is needed, building such a model will take several years.

Balancing the local and the global in organic standards-setting

A second challenge for the future of global organic regulation is to find a way to balance the need to provide consumers with a guarantee that certified organic products produced anywhere in the world meet stringent organic standards with the need to ensure that organic standards are adapted to local production realities. Given the power imbalances, the general trend has been for the jurisdictions with major import markets to require compliance to their own organic regulations rather than engage in a longer and more time-consuming process of searching for equivalence.

To further complicate the situation, when developing country producers seek to sell into two or more different import markets with different regulatory requirements, they must comply with the most stringent aspects of each regulation, which may be in contradiction. Echeverría (2004) compares the EU and USA regulations on the subject of manure utilisation:

> The EU regulation indicates limits to the amount of nitrogen per year/hectare, forbids factory farming origin of manure and says that it should be composted but does not restrict in any way the composting method; while the USA regulation does not forbid factory farming origin or nitrogen use, but it gives very strict instructions on the composting method to be used. The result is, as one can imagine, that our farmers end up having to comply with the most restrictive aspects of both regulations

In addition to the lack of harmonisation, imposing import country organic requirements onto production systems in developing countries with very different farming and socioeconomic conditions creates additional problems (Parrott and Marsden 2002, Raynolds 2004). As an example, EU requirements include lists of permitted inputs that are based on acceptable organic practices in Europe. However, what works as an input in one farming system may not be available, appropriate or widely used (and therefore tested) in another context, leading to contestation; for example, on the use of substances from indigenous botanical extracts, guano and peat to even copper-based substances (Harris *et al.* 2001, Parrott and Marsden 2002).

While IFOAM continuously struggles to maintain this balance, important lessons can be learned from its continuously evolving model, developed through experience in setting and revising international organic standards and in managing an international accreditation system that operates in over 70 countries. Given that IBS are baseline standards for standards and require fleshing out by an accredited certification body to become standards for certification, this has allowed for a balance between the need for consistency in standards in a globalised world and the need for flexibility in adapting standards to local conditions. For better or worse, it has also encouraged growth in the number of public and private organic standards for certification, especially as IBS are not regarded as the only international reference standard.

Although one IFOAM standard is considered necessary for the movement, IFOAM has supported the establishment of voluntary national or regional standards based on the IBS through consensus based processes to reduce the proliferation of standards (IFOAM 2000). While this has not yet been widely adopted by IFOAM regional groups, initial movements are occurring. For example, AgriBioMediterraneo is a regional group of 146 IFOAM members from three continents and 16 Mediterranean countries whose activities include the development of regional standards (ABM 2005). Regional standards would seem to fit well into the proposed revisions to the IFOAM Guarantee system, perhaps enabling regional certification standards to be adopted based on a generic IFOAM Standards norm.

A further tool that was developed to build flexibility into IFOAM standards-setting processes is the development of Criteria for Variation. It is acknowledged by IFOAM that 'there may be conditions where climatic, geographical, technical problems as well as economic, regulatory or cultural factors may require variation to IBS requirements' (IFOAM 2002).

Requests for approval of variations can be submitted to the IOAS for standards comparison and evaluation with the final decision taken by the IFOAM World Board or designated body. Variations may be considered if the need and necessity can be established under at least one of the following conditions:

- the IFOAM Basic Standards (IBS) requirement is ineffective
- where it prevents the development of organic production or processing
- where it prohibits compliance to the legitimate sector regulations and product requirement or
- where it contradicts religious or cultural beliefs of the producers and processors.

Furthermore, the variation requested must be consistent with the principal aims of the IBS (IFOAM 2002).

The first variation to be approved was the American Organic Standard, a private sector standard for North America developed in 2003 by the industry through the Organic Trade Association (IOAS 2003).

The Criteria for Variation approach opens a procedural window to allow for a review of specific aspects of organic standards and the possible granting of exceptions where it can be demonstrated that organic agriculture in a particular local context is best served by such changes. Developing country organisations could use such a tool to argue for the use of particular locally acceptable inputs that serve to meet the broader principles of organic agriculture, among other possibilities. While this has not been widely used yet within IFOAM, perhaps because of the overwhelming and urgent need to resolve the public–private interface of organic regulatory regimes, the approach could be useful as a specific, concrete and short-term solution to the longer-term processes of determining equivalency of entire sets of standards and harmonisation.

Although much work needs to be done in developing organic regulatory structures at an international level that are truly sensitive to the needs of producers and the local realities that they face, a harmonised standards architecture based on general baseline standards upon which local or regional standards can be fleshed out, along with an allowance for justified variations, offer useful models and tools that can be built upon.

Ensuring smallholder access to organic guarantee systems

A specific example of the importance of considering local conditions and realities focuses on smallholder organic production and access to markets. Smallholder producers are important in organic agriculture and contribute significantly to the growth of organic markets. Estimates suggest that 60% to 70% of organic products imported into Europe are produced by smallholders (Agro Eco 2003). Without special consideration, the high financial and administrative costs of organic certification are out of the realm of accessibility for many with only a few hectares under production, if that. This section outlines two new developments in organic agriculture that hold promise for ensuring that smallholders have access to organic guarantee systems. The first is the development and increasing acceptance of internal control systems (ICS) for organic inspection and certification, while the second is the development of participatory guarantee systems.

Internal control systems

One tool that IFOAM and the IOAS developed is a metaregulatory tool, the internal control system (ICS). If a group of hundreds or thousands of farmers was organised in an association of producers, and if the producer association had an internal inspection system whereby local inspectors, be they extension workers or farmers, were trained to inspect other farmers for compliance to organic standards, where inspection reports were maintained for all participating farms and issues of non-compliance were addressed, then an external inspector could come to check on the integrity of the internal control system using a specific sampling technique, rather than doing a 100% inspection of all producers' farms that would otherwise be required. In this way, the ICS is able to reduce the costs of inspection and certification. It should be noted that in the initial stages of development and implementation of the ICS, the human resource costs borne by the producer group are generally significant, requiring considerable human resources, strong farmer commitment and organisational capacity (Harris *et al.* 2001, Giovannucci 2005). However, over time, these costs will be reduced (Pyburn 2003).

Beyond reductions in the costs of inspection and certification, a potentially valuable outcome of the use of the ICS tool in smallholder certification is the empowerment of the producer group. Instead of having external inspectors come in to evaluate progress, the internal control system provides producers and their associations with the ability to take control over the verification of their compliance to organic standards. Ownership of the process by producers can be strengthened through training and capacity building in verification, documentation and monitoring mechanisms. It can also strengthen social control mechanisms of the producer group as it places the decision-making about compliance firmly in the hands of the producer association, at least in the first instance. In one ICS implemented by an organic rice producer cooperative in North East Thailand, producers who had been in the organic program for several years and had seen the changes as a result of the implementation of an ICS, stated that they had become more organised, that they met more regularly together and that they were learning much more than before about the certification process because they were a part of it. While it is more work for them as they are now required to make production plans and record production inputs among other tasks, participation in the ICS enabled them to think about their future plans and the next steps for their farms (Lorenzen *et al.* 2004).

There are different ways in which an ICS can be implemented, however. The example above is illustrative of an endogenous form of ICS where producers are actively involved in ICS management. At the other end of the spectrum is an exporter-led model, whereby a buyer organises producers and controls the ICS through the implementation of external guidelines to regulate the supply chain and outsourced farmers (Pyburn 2004). Further research is needed to better understand the impacts and dynamics of these different expressions of ICS.

Although there is much hope and belief in the ICS process to address the needs of smallholder producer certification, its acceptance by government regulatory authorities has been mixed with disagreement on the technical issues of how to verify such systems, including exactly what external inspection sampling rate is appropriate (see Harris *et al.* 2001, Parrott and Marsden 2002). IFOAM commissioned a series of workshops for certification bodies and government authorities since 2000 to facilitate a discussion and agreement on the role of ICS in organic certification processes. A key challenge is that ICS is partly a soft learning-based capacity-building tool for development, while at the same time, it is a 'harder' verification and inspection tool. Tensions between these different roles are clear. There is a need for flexibility in the application of ICS to different contexts as producer groups are organised differently in various parts of the world. Certain features are needed in common for an ICS to be considered a functional platform for organic certification, thereby making it acceptable to private and governmental regulatory authorities.

Fortunately there has been progress with respect to government acceptance of ICS as a tool for organic inspection and certification. The EU has published a guidance document for the evaluation of equivalence of organic producer group certification schemes applied in developing countries in late 2003. Although this is only a guidance document with no legally binding effects on member states in their implementation of EEC 2092/91 (European Commission 2003), it sets a useful precedent for further development and acceptance and will hopefully provide for a more consistent approach in how member countries handle organic certifications through ICS. The acceptability of ICS has been debated purely at the regulatory level, rather than moving into the realm of market and consumer preferences. Given that the ICS is a tool to reduce the costs of an external inspection rather than replace it, the assurance of independent third party certification is still in place.

Another interesting development is the use of the concept of internal control systems for application in other certification systems that work with smallholders such as Fairtrade and Utz Kapeh certifications. There is also interest in further developing the concept for wider application as a generic management system or total quality management system able to meet additional demands placed on the producer group, such as requirements for food safety systems (Pyburn 2004).

Developments in participatory guarantee systems

While the development and acceptance of ICS is a positive sign for the close to 350 smallholder groups whose organic products are exported, representing 150,000 smallholders (Agro Eco 2003), the current ‘over-regulated’ high-cost environment has led several organic farmers to consider their exit options from these systems. Many farmers wonder why no one trusts them anymore, why they have to pay so much money for multiple organic certifications when they know in their hearts and minds that they are following organic principles. They know that their commitment to organic agriculture is more than securing access to an expanding market, that it is embedded in deeply held values about how agriculture should be practiced. Such frustrations and the high costs of formal certification are causing a counterforce within the organic movement towards a return to simpler regulatory systems, towards organic marketing systems oriented to the local community where formal certification is not necessary because of the existence of interpersonal trust relationships (see (Raynolds 2004). While this movement is gaining momentum, such alternative assurance schemes for local markets have been around as long as the organic movement itself (Altieri 2002).

The counterforce is happening not only in developing countries, where smallholder producer groups are increasingly unable to bear the human resource and financial costs of the management systems and documentation required for certification yet alone the costs of multiple certifications, but also in industrialised countries such as the USA. For example, the North East Farmers’ Association of New York has developed the Farmer’s Pledge, whereby farmers sign an affidavit that can be used as an alternative or complement to mainstream certification (NOFA-NY 2003). Although there is no formal inspection process, customers are invited to inspect farms for themselves to make their own judgements on farmers’ integrity.

Another example of how farmer frustrations with the increasing bureaucratisation of organic regulations are starting to take concrete forms in alternative verification mechanisms such as community-based certification, self-assessment or peer-review systems, is the ‘Certified Naturally Grown’ alternative labelling program for small farms, who grow to USDA organic standards but who see the costs and demanding paperwork of USDA accredited certifications as unnecessary for their local and direct distribution channels (E. Hendersen, pers. comm., 2003). Some small organic farmers have become so disillusioned with the controls imposed upon them by the USDA (see Blackwelder *et al.* 1998), which they argue do not represent the interests of small producers, that they took the USDA to court over the creation of a peer review panel, without which it was feared the US organic standards would be compromised toward the interests of large agribusinesses (Pesticide Action Network North America 2002).

This countermovement is only a small undercurrent in IFOAM meetings, conferences and workshops, but is gaining momentum in discussions among IFOAM members. As a starting point, a first workshop on Alternatives on Certification for Organic Production was held in April 2004. Participating at this workshop were people from 20 countries who represented a wide range of assurance alternatives (e.g. farmers' pledges, second-party assurance schemes, group certification, participatory network assurance). Participating systems ranged from the Teikei system in Japan, a co-partnership between producers and consumers to Centro Ecologico linked with the Ecovida Network of Agroecology in Southern Brazil that functions through network certification with visits made by an ethics commission made up of farmers, consumers and technical consultants.

Most of these systems operate through alternative marketing channels such as box schemes (i.e. local, not-for-profit groups buying and distributing organic food cooperatively), community supported agriculture (CSA) and farmers markets among others, where there is a possibility of developing a relationship with consumers characterised by information exchange and personal trust. An interesting example where the system is integrated into mainstream retail channels comes from New Zealand. The Organic Farm New Zealand scheme was set up to provide an assurance system for an estimated 1500 smallholder organic farmers who did not have organic certification. This scheme uses widely accepted organic standards, and its verification is based on a combination of farmer group peer review, internal inspection and approval by a regional group certification committee (Lernoud and Fonseca 2004a).

Given that there is a general lack of knowledge about the status of alternative approaches and the range of different systems represented within the category of participatory guarantee systems, a main objective of the workshop was to explore and evaluate the range of existing informal methods 'by the people who work with them' (Lernoud and Fonseca 2004b). Strengths and weaknesses of the participatory systems were discussed with a view to gain wider recognition by the organic movement and potentially organic regulators, particularly in countries where regulations are yet to be implemented (Lernoud and Fonseca 2004b).

Participatory guarantee systems can be critical in strengthening local organic markets in developing countries, reducing reliance on exports and contributing to sustainable food security. For example, the absence of a national organic standards in India has helped to engender a 'locally acceptable strategy which involved both producers and consumers', supported by the Institute for Integrated Rural Development in Maharashtra (Daniel 1999 in Harris *et al.* 2001). This involves weekly farm visits ensuring compliance to locally developed guidelines. The wealth of case studies from around the world support claims that local markets for organic products in developing countries could increase significantly in the next few years, provided that consumer confidence in organic assurance can be raised and that availability of organic produce can be increased to local consumers through supermarkets, specialised outlets and farmers' markets (Harris *et al.* 2001).

Although participatory guarantee systems hold great promise for local markets, they will face difficulties in gaining acceptance where there is greater distance between producers and consumers, particularly in key import markets such as the USA and the EU that do not recognise participatory certification (Giovannucci 2005). For those developing country governments that have managed to gain recognition of their domestic regulatory regimes through the adoption of standards and systems that are consistent with key import regimes, they are placed in a difficult bind when it comes to recognising participatory guarantee systems for their domestic markets. Of the situation in Costa Rica, Echeverría (2004) recounts:

> For individual farmers or very small groups, certification costs are just not worth it, since local consumers are usually not in the position to pay an overprice. On the other hand, farmers who are not certified cannot advertise their products as organic and therefore, production and market growth are limited. A working group of NGOs, farmers and others from MAOCO are trying to find alternative ways of certification for the local market, but the task has been hard since the fact that our legislation was made to comply with EU requirements does not give too much room for alternatives.

Creative thinking is needed to find ways to bridge the socially embedded world of participatory guarantee systems with more formal regulatory mechanisms. There may be lessons to learn from countries such as Brazil where 'participatory certification' is placed alongside third party certification in the country's domestic organic legislation (Giovannucci 2005). Further work in such areas is critical to identify and strengthen assurance systems that are appropriate to the particular conditions, scope and scale of organic trade.

Conclusions

One could dream about how nice the world would be if there were no need for standards and control, with everything built on trust. But we have to face reality. The history of the term 'sustainability' shows the growing need to defend the organic movement (Geier 1997).

While reality indeed dictates the need for standards and control of organic agriculture, especially as the scale and scope of organic trade increases, in order for organic regulation to develop into a truly effective and harmonised system, global in scope yet sensitive to local conditions of production, trust needs to return to organic guarantee systems. Organic regulators need to learn to trust each other across national, regional and even public–private boundaries. In order to simplify organic standards and conformity assessment processes and ensure that organic agriculture is accessible to all, organic regulators and consumers need to learn to trust farmers just a little in working out the fine details of organic agriculture.

Activities and mechanisms that enable trust building are key, including the work of the International Task Force on Harmonisation in bringing the various regulatory agencies together to learn more about each others' systems and evaluate the strengths, weaknesses and competencies of the various programs and models. Upon this basis, the slow process of harmonisation can begin.

With respect to the need to balance the local and the global in organic agriculture, establishing the principle of subsidiarity will be most useful. This will ensure that the key principles of organic agriculture are clearly defined and consistently enforced, with the rest of us trusting enough to leave the day-to-day practice of organic farming to farmers who are most knowledgeable about their own local conditions.

Last but not least, work done to strengthen and improve acceptance of internal control systems as a tool for smallholder group certification is urgently needed while the organic movement explores what the formalised regulatory systems can learn from participatory guarantee systems and how they can mutually reinforce each other to create a diverse yet complementary web of regulatory structures up to the task of providing assurance across an even more diverse sector.

References

Agro Eco 2003. *Smallholder Group Certification: Compilation of Results*. International Federation of Organic Agriculture Movements, Tholey-Theley, Germany.

ABM 2005. *About ABM*. AgroBio Mediterraneo/IFOAM, Bonn. <http://www.ifoam-abm.com/english/abm_depth.asp?gumb=1>. Accessed 31/8/05.

Altieri, M. 2002. Non-certified organic agriculture in developing countries. In: Scialabba, N. and Hattam, C. (eds.) *Organic Agriculture, Environment and Food Security*. Food and Agriculture Organization of the United Nations, Rome. <http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/005/Y4137E/Y4137E00.HTM>. Accessed 31/12/05.

Blackwelder, B., Adams, J., Callahan, D., Musil, R.K., Clapp, P., Ris, H., Meadows, W.H., Pope, C. and Krupp, F. 1998. *Letter to the Secretary of Agriculture, Dan Glickman*. Center for Food Safety, Washington, DC.

Boersma, F.V. 2000. Is it possible to export organic produce from the third world to the EU? In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *IFOAM 2000 – The World Grows Organic. Proceedings of the 13th International IFOAM Scientific Conference. Convention Centre Basel, Switzerland 28 to 31 August 2000*. vdf Hochschulverlag AG an der ETH Zurich, Basel. p. 571.

Bowen, D. 2002. International harmonisation of organic standards and guarantee systems. In: *OECD Workshop on Organic Agriculture*. OECD, Washington, DC.

Commins, K. 2002. *The First Ten Years of the IFOAM Accreditation Program*. IOAS, Jamestown.

Commins, K. 2003. *Overview of Current Status of Standards and Conformity Assessment Systems - DRAFT*. International Task Force on Harmonisation, Geneva.

Courville, S. 2001. Social Justice in Organic Agriculture – Global Trends, Australian Issue? In: RIRDC (ed.) *The Organic Challenge: Unity Through Diversity. RIRDC's Inaugural National Organics Conference 2001*. Darling Harbour, Sydney, Australia, 27–28 August 2001. Rural Industries Research and Development Corporation, Barton, ACT. pp. 222–226.

Courville, S. and Crucefix, D. 2004. Existing and potential models and mechanisms for harmonisation, equivalency and mutual recognition. In: Michaud, J., Wynen, E. and Bowen, D. (eds) *Harmonisation and Equivalence in Organic Agriculture*. FAO, IFOAM and UNCTAD, Rome. pp. 50–106.

Daniel, J. 1999. Organic link. *Ecology and Farming* 22: 13–15.

Echeverría, F.H. 2004. Challenges for developing countries' access to equivalency with the main organic exports markets. In: *Proceedings of the First World Conference on Organic Seed: Challenges and Opportunities for Organic Agriculture and the Seed Industry*. FAO/IFOAM, Rome. p. 188.

Ekins, P., Folke, C. and Costanza, R. 1994. Trade, environment and development: the issues in perspective. *Ecological Economics* 9: 1–12.

European Commission. 2003. *Guidance Document for the Evaluation of the Equivalence of Organic Producer Group Certification Schemes Applied in Developing Countries*. European Commission, Brussels.

Geier, B. 1997. Reflections on standards for organic agriculture. *Ecology and Farming* May–August: 10–11.

Giovannucci, D. 2005. *Organic Agriculture and Poverty Reduction in Asia: China and India Focus. Thematic Evaluation*. International Fund for Agricultural Development, Rome.

Grant, W. 1997. *The Common Agricultural Policy*. St Martin's Press, New York.

Grolink 2002. *Newsletters and Press Releases*. Grolink, Höje. <http:/www.grolink.se/newsletter/200002.htm>. Accessed 31/7/05.

Guthman, J. 1998. Regulating meaning, appropriating nature: the codification of California organic agriculture. *Antipode* 30(2): 135–154.

Harris, P., Browne, A., Barrett, H. and Cadoret, K. 2001. *Facilitating the Inclusion of the Resource-Poor in Organic Production and Trade: Opportunities and Constraints Posed by Certification*. Rural Livelihoods Department, Department for International Development, London.

IFOAM 1980. *IFOAM Basic Standards for Organic Agriculture*. International Federation of Organic Agriculture Movements, Tholey-Theley, Germany.

IFOAM 2000. *Policy on Variations in Standards #25*. International Federation of Organic Agriculture Movements, Basel.

IFOAM 2002. *IFOAM Approval of Other Standards #42, Annex 2 – Criteria for Variations*. International Federation of Organic Agriculture Movements, Victoria.

IFOAM 2004. *International Federation of Organic Agriculture Movements*. International Federation of Organic Agriculture Movements, Bonn. <http://www.ifoam.org>. Accessed 31/8/05.

IFOAM World Board 2005. *International Organic Quality System. Proposal for Revising the IFOAM Organic Guarantee System*. International Federation of Organic Agriculture Movements, Bonn.

IOAS 2003. American Organic Standard as regional variation. *Accreditation Update – IFOAM Accreditation Program*. International Organic Accreditation Service, Jamestown.

IOAS 2004a. *IOAS Recognized by NIST*. International Organic Accreditation Service, Jamestown.<http://www.ioas.org/WEBSITE/0410NIST_PRESSRelease.htm>. Accessed 31/8/05.

IOAS 2004b. *List of IFOAM Accredited Certification Bodies*. International Organic Accreditation Service, Jamestown.

ISEAL Alliance. 2004a. *Code of Good Practice for Setting Social and Environmental Standards*. International Social and Environmental Accreditation and Labelling Alliance, Bonn.

ISEAL Alliance 2004b. *Code of Good Practice for Setting Social and Environmental Standards Implementation Manual*. International Social and Environmental Accreditation and Labelling Alliance, Bonn.

ITF 2004. *Short-Term Actions towards Harmonising International Regulation of Organic Agriculture –DRAFT*. International Task Force on Harmonisation and Equivalence in Organic Agriculture, FAO/IFOAM/UNCTAD, Bonn.

ITF 2005. *Third Meeting of the International Task Force on Harmonisation and Equivalence in Organic Agriculture - Report, Second Draft for Comments*. FAO/IFOAM/UNCTAD, Bonn.

Sainsbury's Supermarkets 2005. *Fresh Produce*. Sainsbury's Supermarkets, London. <http://www.jsorganic.co.uk/growingOrganic.asp>. Accessed 31/8/05.

Joint Working Party on Trade and Environment 2002. Government regulations affecting trade in products of organic agriculture. In: *The Development Dimension of Trade and Environment: Case Studies on Environmental Requirements and Market Access*. OECD, Paris. pp. 115–152.

Lernoud, A.P. and Fonseca, M.F. 2004a. *ANNEX – Visits and Workshop Reader*. International Federation of Organic Agriculture Movements, Torres.

Lernoud, A.P. and Fonseca, M.F. 2004b. *Workshop on Alternatives on Certification for Organic Production – Proceedings*. IFOAM, Torres. p. 31.

Martin, W. and Winters, A. (eds) 1995. *The Uruguay Round and the Developing Economies*. The World Bank, Washington, DC.

NOFA-NY 2003. *Farmer's pledge*. North East Organic Farming Association of New York, Albany. <http://nofany.org/farmerspledge.htm>. Accessed 31/8/05.

Nycander, G.A. 2000. *Securing Access to the EU Market: Organic Exports from Developing Countries – Case study on Uganda*. Swedish International Development Authority, Stockholm.

Parrott, N. and Marsden, T. 2002. *The Real Green Revolution: Organic and Agroecological Farming in the South*. Greenpeace Environmental Trust, London.

Pesticide Action Network North America. 2002. News note: organic advocates take USDA to court. *Global Pesticide Campaigner* 12: 27.

Pletcher, J. 2005. Export standards and development in Uganda. In: *International Studies Association Annual Conference*. ISA, Honolulu. p. 53.

Pyburn, R. 2003. *SASA Smallholder ICS Workshop Report*. SASA Secretariat, Nuremberg.

Pyburn, R. 2004. *SASA Final Report on Internal Control Systems and Management Systems*. ISEAL Alliance /Social Accountability in Sustainable Agriculture, Bonn.

Raynolds, L.T. 2004. The globalization of organic agro-food networks. *World Development* 32(5): 725–743.

Ropke, I. 1994. Trade, development and sustainability – a critical assessment of the 'free trade dogma'. *Ecological Economics* 9: 13–22.

Rundgren, G. 2004. IFOAM, a platform for discussion and exchange. In: Lernoud, A.P and Fonesca, M.F. (eds) *Workshop on Alternatives on Certification for Organic Production. 13–17 April 2004. Torres-RS-Brazil. Proceedings*. IFOAM, Bonn. pp. 4–5.

Lorenzen, R.P., Neil, C., Corbo, K. and Courville, S. 2004. *SASA Final Report on Social Standards and Social Auditing Methodologies*. Social Accountability in Sustainable Agriculture, International Social and Environmental Accreditation and Labelling, Bonn.

Segger, P. 1997. World trade in organic foods: a growing reality. In: Maxted-Frost, T. (ed.) *The Future Agenda for Organic Trade. The 5th IFOAM International Conference on Trade in Organic Products. Oxford, England. 24–27 September*. The Soil Association/IFOAM, Oxford/Tholey-Theley. pp. 14–15.

Soto, G. 2003. *Agricultura Orgánica: una herramienta para el desarrollo rural sostenible y la reducción de la pobreza*. FIDA/RUTA/CATIE/FAO, Turrialba.

Swedish National Board of Trade. 2003. *Market Access for Organic Agriculture Products from Developing Countries; Analysis of the EC Regulation (2092/91)*. Kommerskollegium, Stockholm.

Vaupel, S. 2001. *The International System of Standards and Conformity Assessment*. IFOAM, Tholey-Theley, Germany

WTO 1994. *Agreement on Technical Barriers to Trade*. World Trade Organization, Geneva.

Special topic 3

Contradictions of principles in organic farming

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Organic farming has been as much a philosophy of life as a means of food production. Organic farming was a self-renewing, regenerative process, based on nature's principles of production. Recent trends, however, are transforming organic food production into an extractive, exploitative process, based on the principles of industry rather than nature. Economic demands for greater productivity, for consistency and uniformity of product quality and for dependability and timeliness of delivery, are encouraging organic food producers to standardise, specialise and consolidate control. The principles of productivity now driving organic food production are direct contradictions of the historic principles of organic farming.

Philosophical history of organic farming

Organic farming is rooted in the concepts of biodynamic farming, first articulated in 1924 by philosopher Rudolph Steiner in a series of lectures, and later taught by biochemist Ehrenfried Pfeiffer and others during the 1930s and 1940s (Steiner 1974, Pfeiffer 1947).

According to the Bio Dynamic Farming and Gardening Association (2004):

> Central to biodynamics is the concept that a farm is healthy only as much as it becomes an organism in itself – an individualised, diverse ecosystem guided by the farmer, standing in living interaction with the larger ecological, social, economic, and spiritual realities of which it is part.

In this context, the term 'organic' refers to the organisation of the farm as a living system, as an organism. In addition, biodynamic farming was clearly spiritual as well as biological. Steiner was concerned that food grown on increasingly impoverished soil could not provide the inner sustenance needed for spiritual health.

Early advocates of organic farming believed that human health was directly connected to the health of the soil. Soil scientist, William Albrecht, wrote in 1952 (Albrecht 1952):

> Human nutrition as a struggle for complete proteins goes back […] to fertile soils alone, on which plants can create proteins in all completeness.

He later wrote (Albrecht 1966):

> We are slow to study the importance of soil fertility to the quality of food, for this is not yet to our economic advantage in the marketplace.

Organic pioneer and publisher, J.I. Rodale wrote (Rodale 1948):

> The *organiculturist* farmer must realise that in him is placed a sacred trust, the task of producing food that will impart health to the people who consume it. As a patriotic duty, he assumes an obligation to preserve the fertility of the soil, a precious heritage that he must pass on, undefiled and even enriched, to subsequent generations.

Organic farming also has cultural roots in the observations of F.H. King, Sir Albert Howard, and others who attempted to discern the principles of a permanent agriculture in the centuries-old farming systems of the world, particularly in the Far East. In the preface to King's book *Farmers of Forty Centuries* (King 1916), Liberty Hyde Bailey wrote:

> We have not yet gathered up the experience of mankind in the tilling of the earth; yet the tilling of the earth is the bottom condition of civilization.

King's book was an attempt to gather the experiences of 40 centuries of farmers in the Far East. He concluded that organic farming was essential to a permanent agriculture because it returned organic matter to the soil.

Howard began his book, *An Agricultural Testament* (Howard 1940), with the assertion:

> The maintenance of the fertility of the soil is the first condition of any permanent system of agriculture.

Much of his opening chapter (Howard 1940) was then devoted to contrasting the permanent agriculture of the Orient with the agricultural decline that accompanied the fall of the Roman Empire. He wrote:

> The peasants of China, who pay great attention to the return of all wastes to the land, come nearest to the ideal set by Nature. They have maintained a large population on the land without any falling off in fertility. The agriculture of ancient Rome failed because it was unable to maintain the soil in a fertile condition.

Historian, Theodor Mommsen, reflecting on the rise of Rome (Mommsen 1894), wrote:

> Many nations have gained victories and made conquests as the Romans did; but none has equalled the Roman in thus making the ground he had won his own by the sweat of his brow, and in securing by the ploughshare what had been gained by the lance.

G.H. Wrench, commenting of the later fall of Rome (Wrench 1939), wrote:

> Money, profit, the accumulation of capital and luxury, became the objects of landowning and not the great virtues of the soil and the farmers of few acres.

Howard concluded:

> The farmers of the West are repeating the mistakes made by Imperial Rome.

Modern definitions of organic farming

The early advocates of organic farming clearly understood the critical connections between health of the soil, health of people, and health of society. These connections also are recognised in most current definitions of organic farming. For example, the Organic Farming

Research Foundation (OFRF) in the United States of America (USA) defines organic farming as 'a modern, sustainable farming system which maintains the long-term fertility of the soil and uses less of the Earth's finite resources to produce high quality, nutritious food' (OFRF 2004). The International Federation of Organic Agriculture Movements (IFOAM) goes further in defining organic agriculture (IFOAM 2004) as an:

> agricultural production system that promotes environmentally, socially and economically sound production of food and fibres, and excludes the use of synthetically compounded fertilisers, pesticides, growth regulators, livestock feed and additives and genetically modified organisms.

Unfortunately, in establishing national and international standards for organic production, the emphasis has shifted from the purpose and principles of organic farming to the specific inputs, practices, and methods that tend to characterise organic farms.

The historic purpose of organic farming was to ensure the permanence of agriculture, and through agriculture, the permanence of human society. IFOAM (2004) states:

> The purpose of organic agriculture is to optimize the health and productivity of interdependent communities of soil life, plants, animals, and people.

Permanent versus productive agriculture

Healthy, productive, living communities are essential means of ensuring permanence. Living organisms and living organisations are both distinguished by their capacity for permanence. Non-living systems inevitably tend toward entropy. Living systems, however, are capable of capturing, transforming and storing solar energy to offset this inevitable degradation of matter and energy. Thus, permanence is inherently dependent on healthy, living, organic systems of production. Only organic systems are capable of restoring the form, pattern, hierarchy and differentiation inevitably lost in the natural tendency toward entropy. The historic principles of organic farming were the principles of living systems.

The purpose of an industrial agriculture is productivity, not permanence. The principles driving productivity in today's capitalistic market economies are profits and growth. Under neoclassical capitalism, all surpluses or profits must be reinvested in means of production to achieve ever-greater productivity and growth, and profits must be maximised to achieve efficient resource allocation and use. Capitalism allocates nothing to the regeneration or restoration of the ecological or social resources from which it extracts its productivity. Industrial agriculture allocates nothing to restoring organic life to the soils or social life to the communities upon which its long-run productivity ultimately depends.

The processes of specialisation, standardisation and consolidation of control characterise all industrial organisations (Ikerd 2001). Adam Smith, the father of contemporary economics, expounded on the potential gains in productivity that could be achieved through specialisation, which he called 'division of labour'. Division of labour, put simply, meant that each labourer specialised in performing a single task or a limited number of tasks in the production process. By performing fewer tasks, each labourer could perform their specific tasks much more efficiently, and thus, could be much more productive.

Industrial systems also required standardisation to facilitate the division of responsibilities, to ensure that each stage of production could be fitted effectively with previous and following stages. Standardisation allowed specialised processes to be scheduled and mechanised, and allowed producers to obtain and use input materials from several different suppliers. Simplification and scheduling of production allowed each decision maker to manage or control more resources – land, labour, capital – thus facilitating consolidation. Finally, consolidation allowed industrial organisations to achieve greater productivity through 'economies of scale'. Industrialisation inevitably led to fewer, larger, specialised and standardised organisations.

These essential processes of industrialisation, if unchecked, eventually create direct conflicts with the essential characteristics of healthy, living systems. Specialisation diminishes differentiation, standardisation erases form and pattern, and consolidation destroys the natural hierarchy found in healthy, living, organic systems. Industrial systems achieve their greater productivity by removing anything that constrains the release of energy from matter, thus accelerating the tendency toward entropy. The natural environment and society are constraints to maximisation of profits and growth, and thus, are removed. However, natural organic systems have internal controls, which limit their rates of growth and reproduction and define their healthy mature size or scope. Internal controls moderate the release of energy from living systems, releasing surplus energy for external use or productivity, but retaining sufficient energy for renewal and regeneration. Living systems are able to maintain their diversity, form and hierarchy, and thus, to sustain both their health and productivity. The industrial organisation, lacking natural internal controls, grows uncontrollably like a cancerous tumour, until it depletes its energy supply and destroys the life of its host.

The productivity and regenerative capacity of organic systems depend upon an appropriate balance between specialisation and diversity, between standardisation and individuality, and between consolidation and devolution of control. Lady Eve Balfour, in commenting on the definition of organic farming as opposed to conventional farming (Balfour 1977), said:

> I prefer the term biological husbandry because of its emphasis on life, the short answer is balance.

She talked about how organic farming is impossible without taking a 'positive and ecological approach', which relies on balance and harmony, whereas conventional farming is 'negative, narrow, and fragmentary, and consequently produces imbalance', because it relies on specialisation and domination of nature.

The challenge to organics of increased demand

Unfortunately, in efforts to increase the productivity and profitability of organics, to make organic foods more accessible to more people, organic agriculture is being transformed into industrial agriculture. While the objectives may seem worthy, the fundamental purpose of organic farming, its permanence, is being placed in peril by this transformation. As organic farmer and writer, Elliott Coleman (Coleman 2004), has pointed out:

Since the 1930s, organic farming has been subjected to the traditional three-step progression that occurs with any new idea directly challenging orthodoxy. First, the orthodoxy dismisses it. Then it spends decades contesting its validity. Finally, it moves to take over the idea. The industrial food system has finally been forced to recognise a growing consumer preference for organically produced foods, and thus, is now moving to take over organic production.

The rapid growth in consumer demand for organic foods during the 1900s sparked optimism among organic farmers that organic farming might soon displace conventional farming. The patchwork of differing organic standards and certification organisations at the time seemed an obstacle to moving organic foods into mainstream food marketing channels. So, organic farmers initiated political movements to develop national organic standards and then to harmonise organic standards among nations. National and global standards for organic certification would allow organic foods to move freely within nations and among nations, to accommodate the needs of the increasingly global industrial food system.

Ironically, organic farmers may have sown the seeds of their own destruction. The food system that organic farmers were seeking to accommodate is driven by the industrial principles of productivity, not the organic principles of permanence. The industrial food system is characterised by uncontrolled specialisation, standardisation and consolidation, not by maintenance of balance and harmony. National organic standardisation simply opened the door to corporate consolidation of control of organic production and distribution (Kirschenmann 2000).

International harmonisation also forces organic farmers worldwide to conform to a single set of organic standards, with little regard for their specific ecological, social, economic or cultural conditions. Harmonisation of standards pressures organic farmers to harmonise costs of production among nations, forcing returns to organic farmers and farm labourers everywhere toward the minimum achievable by the organic industry anywhere, in a proverbial 'race to the bottom'. This homogenisation of organics removes many of its historic ecological, social and cultural restraints to the exploitation of people and extraction of natural resources globally, in the pursuit of maximum profits and growth.

Not surprisingly, many of the most economically successful of early organic producers eventually came to share the industrial philosophy of production. Their small organic enterprises grew into large industrial organisations (Guthman 2000). Some sold their successful operations to large food corporations, which typically retained their once-respected organic labels. Today, the largest food corporations in the world own most of the organic industry's leading labels, which are distributed by the world's largest food retailers (Cienfuegos 2004).

If the current trend continues, certified organic production might soon be the exclusive domain of industrial-minded producers. The organic producer groups advising governments on organic standards and certification will soon be dominated by producers guided by the principles of productivity rather than of permanence. Organic standards will eventually be changed as needed to accommodate industrial production methods. Other organic producers will be forced by competition to meet minimum standards at minimum costs, forcing them to adopt industrial methods to survive. The industrialisation of certified organic production will then be complete.

Fortunately, industrial organics is not the only viable alternative for organic farmers. Lady Balfour (Balfour 1977) said:

> I am sure that the techniques of organic farming cannot be imprisoned in a rigid set of rules. They depend essentially on the outlook of the farmer.

Her statement of 1977 is still true. The fundamental flaws of industrial organics will become more readily apparent to more people as the concept becomes more commonplace. The widely recognised negative ecological and social consequences of mining, manufacturing and even conventional agriculture are all the natural consequences of the industrial approach to resource management, which inevitably conflicts with the ecological and social health of living systems. As the consequences of these conflicts of principles become more obvious, however, those organic farmers who have remained committed to the historical principles of living systems will find new opportunities.

This principle-based approach to organic farming has been given various labels, including sustainable organic, philosophical organic and deep organic (Balfour 1977, Ikerd 2001, Coleman 2004). All three terms accurately reflect the historical roots of organic farming in ecological, social, cultural and spiritual concepts of permanence. Of the three, deep organic seems the most simple, direct, and thus, compelling.

Deep organic farming

Deep organic is analogous to deep ecology, a term first used by a Norwegian philosopher, Arne Naess, in 1973 (Devall and Sessions 1985). Naess argued that the environmental movement existed at two levels, 'shallow' and 'deep'. The shallow movement was concerned primarily with human welfare issues such as pollution and depletion of natural resources. The deep movement was more concerned with fundamental philosophical issues concerning how humans 'should' relate to their environment. Naess argued that Western philosophy reflects an outdated view of the world, in which humans see themselves as separate from each other and from their natural environment. A deeper understanding, however, reveals that humans are not truly separate or isolated, but instead are integrally interconnected with each other and with the world around them. Humans are 'part of the flow of energy, the web of life'. The early advocates of organic farming clearly understood farms, farmers and their social and natural environment as parts of the same flow of energy and web of life.

Eliot Coleman (Coleman 2004) wrote:

> Deep-organic farmers, after rejecting agricultural chemicals, look for better ways to farm. Inspired by the elegance of nature's systems, they try to mimic the patterns of the natural world's soil-plant economy [...] Shallow-organic farmers, on the other hand, after rejecting agricultural chemicals, look for quick-fix inputs. Trapped in a belief that the natural world is inadequate, they end up mimicking the patterns of chemical agriculture.

Deep-organic farming, like deep ecology, is rooted in philosophy, which asks how we 'should' relate to each other and how we 'should' relate to our natural environment. Deep-organic farming is based on the understanding that humans are not separate or isolated but, instead, are integrally interconnected with each other and with the world around us. Health of the soil, health of people and health of society are integral aspects of the same whole. However, deep organics goes beyond holism and culture-based ethics: it reflects a fundamental belief in the moral and the spiritual, in a higher order of things, in a set of absolute laws of nature, of the universe, to which all living things ultimately must conform. It assumes the existence of rightness and goodness in relationships, which give purpose and meaning to life. Deep-organic farming is consistent with both the biological and spiritual roots of organic farming. Organic farming for the purpose of permanence requires a deep, philosophical commitment to the living principles of permanence.

The principles of permanence are the principles of sustainability. A sustainable agriculture must meet the needs of the present without compromising the opportunities of the future. A sustainable agriculture must be capable of sustaining an ever-renewing, regenerative, evolving, diverse, holistic, interdependent human society, for as long as the Earth receives energy from the Sun, the ultimate source of sustainability. A sustainable agriculture is a permanent agriculture.

Sustainability

The core principles of sustainability are ecological integrity, social justice, and economic viability; in balance and harmony (Ikerd 2001). Sustainable systems need to be managed to achieve balance and harmony between meeting the needs of the present and leaving opportunities for the future. Ecological integrity depends upon harmony and balance between productivity and regenerative capacity of living systems. Social justice depends upon harmony and balance between individual liberty and justice for all. Economic viability depends upon harmony and balance between short-run profits and long-term investments. Sustainable systems must be managed to achieve balance and harmony among the ecological, social and economic dimensions of living systems. The historical principles of organic farming are the principles of sustainable living systems.

These principles of organic farming reflect a deep, philosophical understanding of a rightness of relationships among people and between people and their natural environment. They recognise that a system of farming cannot have ecological integrity unless it is also has social and economic integrity. It cannot be socially just unless it is also ecologically and economically just. And, it cannot be economically viable unless it is ecologically and socially viable. These principles of organic farming are but different aspects of the same web of life and the same flow of energy. Such principles cannot be captured in a set of standards or regulations, and therefore cannot be imprisoned in a rigid set of rules. These principles are written in the hearts, minds and souls of people, in their common sense of right relationships, not just as farmers, but also as consumers, as citizens, and as morally responsible human beings.

The industrial farm, organic or conventional, is driven by the principles of maximum profits and growth, not by the ecological, economic and social principles of permanence. The industrial farmer feels compelled to give priority to the economic bottom line. Industrial farming shows no respect for the wholeness of its living systems; it is about separation, specialisation and dominance. The environment and society are viewed as constraints to economic efficiency, not necessary principles of economic viability. In industrial farming, economic viability is measured in years at most, not decades or centuries, and certainly not permanence. The economic principles of industrial organic farming are direct contradictions of the historical balance of ethical, social, and economic principles in organic farming.

The sustainability of organic farming ultimately depends upon people making a personal commitment to maintaining the health and productivity of self-renewing, regenerative, living ecosystems, societies and economies. Personal commitments require a sense of personal connectedness, thus sustainable organics requires a linking of people and purpose with place. In the words of Wendell Berry (Berry 1990):

> Farming by the measure of nature, which is to say the nature of the particular place, means that farmers must tend farms that they know and love, farms small enough to know and love, using tools and methods that they know and love, in the company of neighbours they know and love.

Berry has never claimed that farmers of the past, conventional or organic, have ever achieved true harmony with nature or sustainability. He simply states that harmony in nature, as with harmony in society, must be achieved through loving relationships. The permanence of food and farming systems depends upon personal relationships of integrity and trust among farmers, farm workers, eaters and citizens within local communities.

Some people may question whether community-based food systems can be realistically expected to feed the people of the world. However, local community-based food systems could be linked together through personal relationships, to form a global network of local food systems. The integrity of the connections between health of soil, health of people and health of society could be ensured locally but linked globally, through personal relationships of integrity among people in different communities. And, when people are connected by relationships of integrity, the result is an equitable sharing of benefits, among farmers, farm workers and consumers, both within and across generations.

This is not some utopian vision of the future. Human life on earth simply is not sustainable unless a sustainable global food system is developed. Humans are no less dependent upon the productivity of the earth for our survival than in times when all humans were hunters and gatherers. Our dependencies are less direct and more complex, but are no less critical. Fifty years from now, when twice as many people may populate the Earth, people will depend no less on the other living things of the earth than we are today. What will they do then, if the non-renewable fossil energy and mineral resources upon which industrial agricultural systems depend have been degraded and depleted? A society characterised by relationships of integrity, among people and between people and the earth, is not some utopian vision: it is a future necessity. A social movement born of the necessity will continue as a post-industrial movement toward a more desirable quality of human life: personally, socially and spiritually.

Hopefully, a growing number of people will soon come to realise that 'shallow-organic foods' are but cheap imitations of the 'deep-organic foods' they were seeking. Growing global environmental, social and economic justice movements indicate that more people are beginning to realise that shallow environmentalism is but a cheap imitation of deep ecology, free elections and constitutions are only cheap imitations of social equity and justice, and free markets are but cheap imitations of economic integrity. As more people seek lasting value through authenticity and integrity in all aspects of life, they will be increasingly amenable to a renewed understanding that all of life in rooted in the soil.

The future of humanity literally depends upon a return to the historic principles of organic farming. Global society today depends no less upon the fertility of the soil than during the days of the ancient farmers of China or the farmer-warriors of Rome. The health of society and the health of people still depend upon the health of the soil. The absence of commercial chemicals will not ensure a healthy agriculture, as proven by farmers from ancient Rome to the mid-20th century. The sustainability of human life on Earth depends upon keeping farmers who are committed to the principles of sustainability on farms small enough to know and love, in the presence of neighbours that they know and love, providing food for people that they know and love. The people of a society committed to relationships of integrity will reconnect with farmers who are committed to the organic principles of permanence, allowing both farmers and society to sustain prosperity – economically, socially and ecologically.

References

Albrecht, W.A. 1952. Protein deficiencies ... through soil deficiencies. *Let's Live Magazine*. December.

Albrecht, W.A. 1966. Balanced soil fertility - better start of life. *Let's Live Magazine*, December.

Balfour, E. 1977. Toward a sustainable agriculture - the living soil. In: Besson, J.-M. and Vogtmann, H. (eds) *Towards a Sustainable Agriculture/ Auf dem Wege zur nachhaltigen Landwirtschaft/ Vers une agriculture viable. Proceedings of IFOAM International Organic Farming Conference. Sissach, Switzerland*. Wirz Verlag, Aarau. pp. 18-27.

Berry, W. 1990. Nature as measure. In: Berry, W. *What are people for?* North Point Press, New York. p. 210.

Bio Dynamic Farming and Gardening Association 2004. *Biennial Report*. Bio Dynamic Farming and Gardening Association, Junction City.

Cienfuegos, P. 2004. The organic foods movement – led by Heinz Corporation or we the people? Time to choose is now. CropChoice, Washington DC. <http://www.cropchoice.com/leadstryfa91.html?recid=2595>. Accessed 21/8/05.

Coleman, E. 2004. Can organics save the family farm? *The Rake Magazine*. September.

Devall, W. and Sessions, G. 1985. Deep ecology. In: Devall, W. and Sessions, G. (eds) *Deep Ecology: Living as if Nature Mattered*. Gibbs Smith, Layton. pp. 63-77.

Guthman, J. 2000. *Agrarian Dreams: The Paradox of Organic Farming in California – Case Studies in Critical Human Geography*. University of California Press, Berkeley.

Howard, A. 1940. *An Agricultural Testament*. Oxford University Press, Oxford.

Ikerd, J. 2001. The architecture of organic production. In: RIRDC (ed.) *The Organic Challenge: Unity Through Diversity. RIRDC's Inaugural National Organics Conference 2001. Darling Harbour, Sydney, Australia, 27-28th August 2001.* Rural Industries Research and Development Corporation, Barton. pp. 23-28.

IFOAM (International Federation of Organic Agriculture Movements). 2004. *FAQ. What is organic agriculture?* IFOAM, Bonn. <http://www.ifoam.org/sub/faq.html>. Accessed 21/8/05.

King, F. H. 1916. *Farmers of Forty Centuries or Permanent Agriculture in China, Korea, and Japan*. Dover Publications, London.

Kirschenmann, F. 2000. The hijacking of organic agriculture… and how USDA is facilitating the theft. *Ecology and Farming*. May-August.

Mommsen, T. 1894. *History of Rome, from the Union of Italy to the Subjugation of Carthage and the Greek States*. Dickson, London.

OFRF (Organic Farming Research Foundation). 2004. *Frequently Asked Questions About Organic Farming* OFRF, Santa Cruz. <http://www.ofrf.org/general/about_organic/index.html>. Accessed 21/8/05.

Pfeiffer, E. E. 1947. *The Earth's Face and Human Destiny*. Faber and Faber, London.

Rodale J. I. 1948. *The Organic Front*. Rodale Press, Emmaus.

Steiner, R. 1974. *Agriculture: a Course of Eight Lectures Given at Koberwitz, Silesia, 7th to 16th June, 1924*. Bio-Dynamic Agricultural Association, London.

Steiner, R. 1993. *Spiritual Foundations for the Renewal of Agriculture: A Course of Lectures*. Bio-Dynamic Farming and Gardening Association, Kimberton.

Wrench, G.T. 1939. *The Restoration of the Peasantries*. C.W. Daniel Company, London.

Chapter 10

Economic management in organic agriculture

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Introduction

The old question, 'But is it profitable to farm organically?' will always be with us, at least for those who have not followed organic agriculture closely.

The answer to this question is that 'it depends'. Whether land under organic management can be as productive as conventional farming depends on, among other factors, what is included in the comparison. How long is the time frame under consideration? Looking at any time within the first period of one rotation is not likely to show organic agriculture in a positive light. Similarly, if only the private (on-farm) costs are considered while neglecting the public (off-farm) costs or externalities, such as consumer and environmental health, the organic system may not always compare well. The willingness of some consumers to pay extra for organic produce, or of some governments to support organic agriculture, reflects the thought that these externalities should be counted. The taxing of certain agricultural inputs such as pesticides, as some Scandinavian countries do (Schou and Streibig 1999, Jesper Schou, pers. comm. 2005) is another way in which to acknowledge and force producers to internalise externalities of agricultural activities. It aids in redressing the difference in agricultural production costs between the two systems, thus influencing the answer to the profitability question. But, one may say, even if farmers can make a living when receiving premiums and subsidies, what are the chances that organic farming can feed the world without destroying it – as some would like us to believe that that is what would happen with increasing conversion to organic management (Avery 1995).

Economic management

Established farms

Many in organic agriculture have moved on from whether organic agriculture works to how it works, and finding efficient solutions for if and when it does not work. Already in the 1980s, there was a movement away from comparing farm results between the two systems towards exploring different options on an organic farm (Dlouhy and Nilsson 1983). Despite this resolution, comparisons continued in many countries, if only to provide a reference to changes under organic management.

Klepper *et al.* (1977) published one of the first and best-known economic comparisons between organic and conventional farming in the United States of America (USA), with a follow-up by Lockeretz and Madden (1987). Several other surveys were published, such as in the United Kingdom (UK) by Murphy (1975) and Vine and Bateman (1981). In the early 1990s, Lampkin and Padel (1994) pulled together, in an edited volume, studies in many countries (from Europe, USA, Canada, Australia) and analysed many aspects of organic agriculture. Topics encompassed physical (yield, production) and financial (input costs, output prices, total farm receipts) variables of both established farms and those in conversion. This survey also included modelling widespread conversion to organic farming in different countries. Since then, other studies have been published that consider the differences between the two systems in some or all of those concepts, such as Penfold *et al.* (1995), Smolik *et al.* (1995), Reganold (1995), Wynen (1998), Clark *et al.* (1999), Offermann and Nieberg (2000), Wynen (2000), Stonehouse *et al.* (2001), Butler (2002), Pacini *et al.* (2002), Mäder *et al.* (2002), Nieberg and Offermann (2003), Delate *et al.* (2003), and Smith *et al.* (2004). Nicholas *et al.* (2004) provide an overview of studies carried out in the organic dairy industry. As many different combinations of profitability to different factors (e.g. land, labour) were analysed in Lampkin and Padel (1994), the studies carried out since then have served to highlight prevalent aspects in particular industries, under certain climatic and soil conditions, in particular geographical areas and within a particular policy framework. In some of the later studies particular topics (apart from financial returns) such as measures of sustainability and energy efficiency have received more emphasis.

No attempt is made here to write an exhaustive treatise of the economics of organic agriculture. Rather, the aim is to highlight key issues affecting returns to management in organic agriculture, often comparing them with returns to management on a conventional farm. Production, input costs, output prices, premiums and subsidies are discussed to arrive at the farm profitability on established organic farms.

Production and productivity

Productivity is production related to inputs. Productivity is often equated with production (e.g. tonnes of grain, head of cattle) per unit of land (hectare), but productivity could also be measured as output per unit of labour, energy or water used, or investment. Many assume that agricultural production per hectare under organic management is lower than under conventional management. Although this is often the case, it is not necessarily so. There are some general rules that can be observed.

Yield changes (changes of production per hectare or animal) are often relative to the intensiveness of the enterprise before conversion. This is true within enterprises (e.g. changes on intensively farmed cereals are larger than on extensively farmed cereals after converting to organic management) and between enterprises. For example, changes in yields in intensively run horticultural enterprises may be different from those in intensive cereal–livestock farming after conversion. In countries with a relatively high percentage of agriculture in extensive industries, such as dairy farming as compared with crops only, more farmers tend to convert to organic agriculture (e.g. in Austria and Switzerland), possibly reflecting the ease of conversion within this industry compared with other industries.

As the intensity of agriculture in a certain industry, say cereal–livestock, differs between countries, figures for changes in yield due to a change in management system also differ between countries. For example, reductions in crop yields after conversion were up to 40% in some European countries such as the UK, Germany, Denmark and the Netherlands in the 1990s, while those in Australia, Canada and the USA were between 10% and 20% down and were, in some cases, even higher than those under conventional farming (Lampkin and Padel 1994, p. 202). Mäder *et al.* (2002) mentioned yield decreases of 20% to be normal in organic systems in Switzerland, and Nieberg and Offerman (2002) found typical grain yield decreases of between 30% and 40% in several European countries.

For dairy, yield changes are more similar between countries. Yield changes per cow per year reported by Lampkin and Padel (1994, p. 203) are about 10% and stocking rate 20% to 30%, resulting in a reduction of milk yields of 30% to 40% per hectare. Nieberg and Offerman (2002, p. 143) mention a decrease of up to 20% in European countries per cow per year, and between 20 and 40 of cows per hectare. In Australia, Wynen (2000) recorded a decrease in milk litres per hectare of between 30% and 35% on seven pairs of farms. In Canada, Stonehouse *et al*. (2001) found average milk sales per cow on 7 organic farms to be 4% down compared with 111 conventional dairy farms, and those per hectare were 41% lower. In the USA, average milk sold per cow was 13% lower on six organic farms compared with 27 conventional enterprises in the same region, while no figures on stocking density were provided (Butler 2002).

In developing countries, where the choice for organic agriculture is often made in the context of no-use of pesticides and fertilisers, the United Nations Food and Agriculture Organization (FAO) mentioned that organic management may even increase yields (FAO 1998, Scialabba and Hattam 2002, see *Chapters 4* and *5*). Very few data are available for developing countries.

The cost of production

Yield is not the only indicator of farm productivity. Inputs used to deliver those yields should also be considered, and can be in the form of materials, as discussed below, but they may also be in different forms. For example, one way to manage soil fertility and pest problems on organic farms is to employ a different rotation from that on conventional farms where synthetic fertilisers and pesticides can perform those tasks. Because of the difference in rotation, which may also mean a larger diversity of crops, the whole farm needs to be considered when determining productivity and profitability.

For the farmer, the net profitability of the farm is important (i.e. what is left of the total receipts when all costs have been paid). For the profitability of the farm, the input costs can be as important an issue as the quantity produced and the prices received for the production.

In many agricultural enterprises, organic farmers may use fewer inputs such as fertilisers and pesticides and sometimes more labour, such as for hand-weeding, than on conventional farms. This is not necessarily the case, as materials to manage nutrients and pests on organic farms such as mineral fertilisers, compost and pheromones can also be costly.

Padel and Lampkin (1994, pp. 206–207) reported total variable costs to be typically 50% to 60% lower for organic cereals and grain legumes; 10% to 20% for potatoes and horticultural crops; and 20% to 25% for dairy cows, mainly due to reduced concentrates. For pigs and poultry, the extra cost of organic feed often means no reduction in average input prices.

Padel and Lampkin (1994) also summarised the fixed costs. Labour (classified as fixed costs) is seen to be mainly higher on organic farms, while other costs including power, repairs, depreciation of machinery, property charges and depreciation and capital costs were reported as similar in most countries, though higher in Germany and lower in Australia. However, in a later survey among Australian cereal–livestock farmers, this difference was much less pronounced than in the earlier study, or non-existent (Wynen 2001).

Labour cost is often controversial as it differs greatly between industries. For example, it is more likely to be similar or higher in intensive industries (e.g. horticulture, where labour can contribute considerably to replace herbicides) than in extensive industries (e.g. large-scale cereal growing). However, there can also be variations within industries. For example, labour costs were found to be similar or lower in studies on dairy farms in Australia (Wynen 2000) and Canada (Stonehouse *et al.* 2001), but higher in the USA (Butler 2002).

Output prices and premiums

In relation to price premiums, it is important to discuss the more recent studies, as this variable is rather dependant on time. Nieberg and Offerman (2002) reported on premium prices on wheat, milk and beef between 1994 and 1997 in several European countries. For wheat, typical premiums were between 50% and 200%; for dairy, between 8% and 36%; and for beef, premiums tended to be between 20% and 30%. For the last two categories, the average premiums were low, at least partly because some of the product was sold on the conventional market without premiums.

Hamm *et al*. (2004) estimated that premiums for cereals in the EU countries in 2001 reached just over 100%. For oilseeds, the premiums were recorded as 70%, for potatoes 166% and for wine 32%.

In Australia, Halpin and Brueckner (2004, p.70) reported average price premiums of all organic goods to be 80%. Several products scored over 100%, such as wholemeal flour, muesli, olive oil, spaghetti (the highest was 287%), several vegetables (beans, zucchini, carrots), hard cheese and minced beef.

However, not all organic products are sold on the organic market, and percentages of produce receiving a premium can vary considerably. For example, the range in Australia was estimated to be between 10% (sheep meat) and 95% (fruit and vegetables) being sold in the organic market in 2000 to 2001, with almost three-quarters of the total grains sold as organic, two-thirds of beef, and half of the organic milk supply (Wynen 2003).

Profitability

A general picture emerges of lower yields and productivity per farm, lower input costs and higher output prices on organic farms than those on conventional comparisons. The results in the different studies included in Lampkin and Padel (1994) ranged from lower net returns in the studies in the USA, UK and Switzerland, similar in Australia and higher in studies from Germany, Denmark and Wales.

Inclusion of premiums is, of course, an important determinant of the results. In some countries, such as those in Europe, premiums were more common than in others. In the Australian study (Wynen and Edwards 1990), for example, very few farmers received premiums at the time of the first survey in the mid-1980s. In a later study, all farmers received premiums though the net farm returns were variable, being similar to those of conventional neighbours in one year and considerably lower in the next (Wynen 2001). Obviously, factors other than price premiums may be of greater significance in the total picture.

In several different studies on both arable and dairy farms in ten European countries, net profits per hectare on organic farms were mainly within 20% of conventional farms (Nieberg and Offermann 2002). When the measure was profit per family work unit, the results for organic farmers were found to be similar or better than for conventional farmers. Profits varied considerably both by locality (country) and type of enterprise. Arable organic farms in particular were doing well, though specialised, highly intensive farms were generally not profitable under organic management. The figures included premium prices and subsidies for organic and conventional farming, which were important contributory factors in the profit figures. Not many data were available for horticultural, pig and poultry farms, possibly indicating that few farmers had converted to organic management in those industries.

In a time series analysis of data for five countries (Switzerland, Germany, Austria, the Netherlands, Denmark) between 1990 and 2001, this same study showed mainly higher profits per hectare on organic farms. Annual results on organic and conventional farms follow very similar patterns, indicating that outside factors such as climate, prices and policies are rather more important for the profitability of the farm than the difference between the two systems.

In the dairy study in Australia, biodynamic farms showed a considerably lower net return over the three years surveyed than their conventionally farming neighbours, though their returns were similar compared with all farmers of the area (Wynen 2000). These results were achieved with no or low premium prices for the biodynamic milk. To reach similar returns to those of their conventional neighbours, the biodynamic farmers would have needed a premium price of about A$0.10 per litre of milk, a premium not considered extravagant in some other countries. The study in Canada (Stonehouse *et al.* 2001) showed a 12% lower net income per hectare on organic farms, though the return was 1 percentage point higher for the organic farms as returns on total assets. The USA study showed 16% lower net income per litre of milk produced (Butler 2002).

Conclusion for established farms

Looking at the different studies over time on the comparability of organic and conventional management systems, the results of the net returns and their components of yield and total production, input costs and output prices are variable. In some studies net returns were found to be lower, and in others similar or higher. The question of comparative profitability is unlikely to be answered definitively, as the results depend on many factors, only some of which are within the farmer's control. The management of the farm and decisions about which crop to grow where, or even which enterprise to include, are somewhat under the farmers' control. Climate and soil type, input and output prices, premiums and subsidies depend on the particular country and time in which the farmer lives, with policies changing over time. Perhaps, the inclination of the organic movement to minimise comparisons of the system in the 1980s was reasonable, especially if they were carried out to convince the conventional sector that investment in this system was warranted, rather than to find where the change in management system impacted most, and how to make the system work better.

In the debate about whether it is financially rewarding to farm organically, the question of what to include in the final analysis remains. The private benefits to the farmer are included. From society's point of view, another relevant factor is the difference in off-farm effects between the two management systems. This is notoriously difficult to quantify but is still relevant for the full picture of the total efficiency of the systems. In some of the studies discussed, this factor is already included in the form of subsidies and premium prices, though these extra revenues must also cover the extra cost of small-scale marketing.

So, the answer is not clear cut. The studies discussed here indicate that the results can be positive for organic farmers, but do not necessarily need to be so. When considering conversion, the farmer would be wise to take several factors into consideration, including the physical attributes of the farm and the farmer, marketing possibilities and the political climate in the country at that time.

Conversion challenges

Whether a farmer can become an established organic farmer and not go bankrupt in the process depends on several factors. Important in this connection is the capacity of the farmer to adapt to a different way of management, and the ability to consider availability of farm resources on the history of the fields, market possibilities and political climate. This last issue involves government support in the form of, for example, production subsidies and research funding or reducing hurdles through regulations that hinder organic production and marketing. Lampkin and Padel (1994) devoted several chapters to the effect of conversion in several countries, and quote several early studies. In Australia, the process of conversion in the cereal–livestock industry was analysed by Wynen (1992).

Whatever the physical and financial problems of transition to organic agriculture may be, possibly one of the most difficult to overcome are the misconceptions about whether organic agriculture could work, and if it does, how. Lack of information about what changes are needed, and how to implement those changes, has always been mentioned as a major problem. Managerial ability, being able to manage the farm in a way appropriate to the system (e.g. handling different varieties, changing seeding dates to beat pests, recognising problems before they cause great damage, and having knowledge about solutions) is an important first requirement.

In the first years of moving towards organic management, most farmers have some special physical problems that they are unlikely to experience once the system is established. A biological change towards a different equilibrium in soil biota is one conversion aspect that may take time. Soil microorganisms essential for organic management need to become established. For example, Australian organic grain farmers reported that as they did not burn straw under the organic system, they experienced problems during transition with planting and germination of seed due to the straw blocking up the machinery, necessitating adaptation of their planting machinery. However, after those first few years the straw did break down considerably faster, presumably as a result of build-up of fungi over time. The absence of specific biological activity may also be part of the cause of yield reductions reported by some farmers in early years compared with yield levels further into the conversion period.

A change in farm layout is often advisable when changing management systems, and would require resources. For example, changes in rotations and livestock use within the rotation may require extra capital expenditure for fencing and livestock purchase. However, on farms where livestock require concentrates that are sourced off-farm, the change may mean some form of decrease in stocking rate.

Extra farm storage to cope with a change in marketing strategy can be another reason why more investments are needed. Buyers of farm produce may not have separate storage space for organic products, although this problem may decrease over time.

At the same time as the issues of change need attention and action, farmers can usually not count on premiums for the products. In the first phase of organic management, a farmer can be certified only as being in conversion. This means that during this time, premiums are less certain than at a later stage when the farm is certified as fully organic. The length of this period differs between countries, but is typically between one and three years.

Whatever problems arise, the farmer needs to plan well ahead, and analyse possible scenarios under conversion that encompass changes, including the use of existing resources, the need for investments, possible changes in yields and total productivity, availability of labour and machinery, accessibility to markets and likely output prices and cash flow.

Risk and uncertainty

Changing from conventional to organic agriculture means taking risks and facing different uncertainties. The risk during conversion is made up of the factors just discussed (see *Conversion challenges*), changes to the soil biota resulting from farming system changes, a steep learning curve for farmers regarding general organic farm management with particular emphasis on the characteristics of each particular farm, and a possible need for more investments in machinery, fencing, livestock and storage while outputs and marketing may be in flux. These risks can be expected to decrease over time as the physical processes settle down and the farmer learns more about the management system requirements.

However, differences in production variability may be a more permanent feature of the two management systems. Yields on organic farms that are closer to the average in extreme years are mentioned in the early literature (e.g. Klepper *et al*. 1977), but not always found (Padel and Lampkin 1994, p. 216). One study that did find a correlation between organic management and decreased variability of wheat yields was carried out in Australia (Wynen 1994), where extremes in weather conditions are not uncommon. Almost a decade later, Lotter *et al.* (2003) concluded that in plots with two organic systems at the Rodale Institute in the USA, yields were higher in four of the five drought years, while the fifth year gave mixed results. The authors attribute the difference in yields under extreme conditions between the systems to the higher water-holding capacity of the soils in the organic plots.

Variability in output prices for organic products depends on local arrangements, with possibilities ranging from fixed prices for a particular period, to a fixed percentage or amount on top of conventional prices, to a totally deregulated market. Variability in income resulting from changes in farm output prices is determined more by outside factors than by organic management *per se*.

Large-scale conversions

What happens when many farmers move towards organic agriculture? This question usually centres around the assumption of collapsing premiums, leading to lower farm incomes. Several studies on large-scale conversion in Germany, the German state of Baden-Wuertenberg, England and Wales are detailed in Lampkin and Padel (1994). Other studies are also discussed or summarised in that work. Later, Wynen (1997) conducted a study on a large-scale conversion in the cereal–livestock industries in Australia, its largest agricultural industry, and on the whole of the Danish agricultural sector (1998).

These studies must make assumptions about changes in, for example, future input and output prices, yields, subsidy and premium levels, the way consumers and producers will react to changes in prices (price elasticities of demand and supply), population increase or decrease and level of adoption. The possible outcomes are too numerous to summarise here, so only a few results are presented as examples.

Farm incomes are the variable considered most often in this respect, but they are not the only variable affected by a large-scale change to organic farming. As organic management requires a change in rotation for soil fertility and pest management reasons, a change of management system by many farmers would make a substantial change to the land use of a whole country. Hence, there will be a change in the relative importance of total output of different products and in output prices at the national level, and effects on farm incomes at state and individual levels. Other factors not discussed here that are sometimes analysed include food security, employment and income in related industries, environmental and social benefits and public expenditure (Midmore and Lampkin 1994).

The direction and magnitude of the changes in production and returns will differ between countries. In the UK, for example, Lampkin (1994) estimated that with a 10% increase in organic agriculture, there would be a decrease in wheat, barley, potatoes, sugar beet, oilseed and livestock and an increase in oats and field beans. In Australia, on large-scale cereal–livestock farms, large-scale conversion would lead to decreased total production of all cereals (wheat, oats, barley, canola), and an increase in sheep (Wynen 1997).

The same Australian study estimated total farm incomes under the assumption of an adoption rate of 30%. Under the worst-case scenario, where premiums for crops were assumed to decrease from 15% to 0% with no premiums for livestock products at all stages (extreme assumptions) total returns to the sector would drop by 7% when 30% of farmers had converted. In the best-case scenario, with premiums decreasing from 15% to 7.5% (probably more realistic), total returns to the cereal–livestock sector would have a 3% decrease at the 30% adoption rate.

Many studies have been based on the assumption that a very large proportion of the farming sector becomes organic – often 100%. However, this is rather unlikely, and would certainly not happen under conditions that are easily imaginable. More likely is that when, say, 10% or 20% of farmers have converted, political pressure may result in, for example, more research relevant to organic farming, information systems more readily accessible to organic farmers, decreased consumer prices as a result of decreased marketing costs (economies of scale) with a resulting increase in demand for organic food, and confidence of conventional farmers to convert. The detailed study on the Danish agricultural sector assumed initially that 80% of farmers converted to organic agriculture, and also analysed what happened at lower levels of conversion (Wynen 1998). The results showed that with prevalent input and output prices, and assumptions of reducing premiums with an increasing number of farmers across all industries, the total receipts to the farming community would start to fall only after about 25% of farmers had moved to organic farming. If that situation were reached, the political and social climate within the agricultural sector would have changed substantially, warranting new estimations with assumptions closer to reality than those available now.

In summary, studies have been undertaken to examine the consequences of large-scale changes towards organic management among farmers. Total production is usually the main factor considered, although total returns to farming and to farmers were also analysed. Studies mentioned here indicate that conversion to organic management, especially when the conversion rate is not taken to extremes, would generate few changes that cause adjustment problems to the agricultural sector.

SWOT analysis

The market for organic produce has developed considerably. In 2000, the global retail market was estimated to be around US$16 billion, with an estimated annual growth in demand of about 15% to 20% in several markets. Estimates for 2001 were closer to US$20 billion, and forecasts for 2003 for the world organic food and beverages market were between US$23 billion and US$25 billion (ITC 2005). Organic food and non-food sales grew by about 20% during 2003, and reached US$10.8 billion in one of the main markets, the USA (Organic Trade Association 2004). The ITC estimate for the organic retail market reached US$30–32 billion in 2005 (Kortbech-Olesen 2006). A general upward trend can be detected, which shows that both the demand and supply of organic products are growing.

Strengths and opportunities

Significant body of knowledge and expertise

Organic farming has become more popular since the 1980s (Foster and Lampkin 1999, Tuson and Lampkin 2006). This growth has been stimulated by, and has stimulated, an increase in know-how and managerial skills on farms. Although globally there may not yet be many people who have a profound knowledge of organic agriculture, experience in many kinds of applicable disciplines such as farm management (farmers), soil science, plant pathology, entomology, veterinary science, plant and animal husbandry, marketing, economics and political and social science is now available.

Standards and certification in many countries

For farmers to be able to sell their products, consumers require sufficient confidence in the organic production and marketing processes to be willing to buy. Over the last 20 years, considerable effort has been expended by both public (state authorities) and private (e.g. farmers' associations) organisations into developing a well-functioning certification scheme. As a result, many countries have credible organic standards and certification procedures.

Availability of markets

The demand for organic products has increased especially during crises in conventional agriculture. Examples include 'mad cow disease' since the late 1980s, the presence of dioxin in feed in Belgium in 1999, and foot and mouth disease in the UK in the early 2000s. The increase in demand in many places, especially Japan and China, should provide future opportunities for organic production.

Weaknesses and threats

Standards and certification

Keeping to standards

Just as organic agriculture benefits from food scandals in the conventional market, it also suffers when a scandal occurs in the organic market, for example with producers, certification offices and through accidental problems.

With organic produce commanding premium prices, unscrupulous conventional farmers may be tempted to sell their produce on the organic market. This is a potential problem especially in markets where the word 'organic' is not legally defined. In Australia, for example, the potential for two problems arises because standards cover requirements for the export market, but the term 'organic' has not been defined for the domestic market. The first is the possibility of fraud in the domestic market, where there is little possibility of recourse; and other problems could occur in the import market where, due to World Trade Organization rules relating to national treatment, the Australian government cannot prohibit imports and sales of non-certified products labelled as organic. Second, certification organisations may be tempted to cut corners. In a market where all produce needs to be certified and certification organisations vie for business, such behaviour is conceivable in a bid to provide the cheapest certification service. Third, accidents can also be problematic. In mid-2002, poultry feed on more than 100 German organic chicken farms was contaminated with the pesticide nitrofen. The feed had been stored in a warehouse previously used for pesticide storage (Deutsche Welle 2002).

International trade

Standards and certification for organic agriculture have developed over time. Originally, many countries, or organisations within countries, developed standards and systems suitable for their local circumstances. These were not necessarily based on scientific principles, or principles that were accepted in the scientific community. Although such problems are slowly being addressed, many remain.

The differences between standards and compliance systems among countries can make international trade problematic for exporters because exporting countries need to comply with the requirements of the importing countries. As the main importing countries have different standards and certification requirements (see e.g. Schmid 2003, Commins and Kung Wai 2003), complying with the requirements of the importer can become costly. This issue is one that the International Task Force set up by the United Nation's Conference for Trade and Development (UNCTAD), the FAO and the International Federation of Organic Agriculture Movements (IFOAM) has been trying to solve since 2002. The problems can be daunting for farmers in many countries, especially developing countries that do not have their own certification schemes (Wynen 2005).

The problem of different organic standards and certification for imports is compounded in some countries by private certification schemes that convince local supermarkets to accept only products certified by the particular private certification scheme. A similar effect is achieved by local certifiers promoting produce from local producers, such as the UK Soil Association, which mentions in the Organic Action Plan a target of 70% of organic primary products to be sourced from the UK (Defra 2005). Thus, not surprisingly, the contention of some exporting countries is that organic import requirements aim to keep competition out and benefit local producers rather than to provide consumers with a guarantee that the product was organically grown, which was the main aim. The issue of regional standard appropriateness is not controversial. The problem is, however, to find efficient ways to facilitate international trade in the presence of regional standards and certification procedures.

The issue of acceptable differences in standards is also an area that needs more attention, as many standards are not based on scientific considerations. One example is the conversion period, which determines the time farmers have to wait before they are eligible to be called organic. This provides easier access to premium prices. At the international level, the conversion period is set in different ways. For example, IFOAM has a conversion period of 12 months for plant production, while the EU and the Codex Alimentarius Commission (part of the FAO and World Health Organization's food and veterinary standards activities) require a minimum of between two and three years, although the conversion period can be reduced to one year if certain requirements are met (Schmid 2003). Importing countries that set the conversion period at a certain level do not take into account the possibly legitimate claim by some exporters that a decrease in conversion for their local circumstances may be appropriate. For example, if the conversion period is meant to provide time for the breaking down of substances that have no place in organic agriculture or for positive agents to build up, this process will be influenced by local conditions, such as climate. Variable conversion periods in countries with different climates would be appropriate.

Consumer prices

Apart from the importance of consumer confidence in the product, which is encouraged through a trustworthy and known certification scheme, a stable supply (e.g. through the involvement of supermarkets) and relatively low prices are important for organic agriculture to expand (Michelsen *et al.* 1999).

In general, produce sold as organic commands higher prices than conventionally grown produce of equal quality. Many surveys have shown that consumers are willing to pay more for these products, though the demand is highly price sensitive (see Weir *et al.* 2003, and references therein). Demand rapidly shifts towards conventional products with increasing prices for organic products.

Though output premiums for farmers are often blamed for high consumer prices, for many products the farm price is only a small part of the final consumer price. Other components such as transport, wastage, processing, handling and sales also influence the retail price. One would expect that for many products with low sales volumes, costs would be relatively high per unit; however, the lack of institutional facilities for organic products is also likely to affect costs. This has been recognised by for example the Dutch and Danish governments who devote a relatively large part of their organic agriculture support in encouraging and promoting the increased efficiency of the supply chain for organic products.

Governmental regulations

Differences in government support between countries can lead to an unfair advantage for producers in countries with regulation compared with those where no regulations exist. For example, subsidies for organic farming in one country, be it in the form of direct payments for farmers, research subsidies, or the development of a national certification scheme, can affect the price and the quantity of production in that country. This means that producers in other countries will need to produce more efficiently in order to be able to export to those countries. In other words, an advantage for farmers in some countries means a disadvantage for some farmers in other countries. Some governments, especially those of EU countries, support organic agriculture (see EUROPA 2005 for the European Action Plan).

Subsidies have an additional benefit to increasing farmers' income – farmers are able to sell their produce more cheaply, thereby reducing consumer prices and therefore demand. However, the potential for price reduction is likely to be tempered by increased input costs, especially those of land.

Conclusions

In this chapter, the economics of organic agriculture for farmers is considered, which includes issues surrounding yields, inputs, outputs and returns to farming. Off-farm effects are not considered here. In general, the financial results can be positive for organic farmers, but are not necessarily so. Details about the local situation are important for the results, such as the history of the farm, the particular enterprise, prevailing input and output prices, and domestic and international policies. The question also arises how easy it is to get to the state of organic management without failing financially in the first (transitional) stage. Important factors for success include planning for conversion related to the use of existing resources, the need of investments, changes in yields and total production, input availability and prices, marketing opportunities and cash flow. As whole-country transition to organic farming would influence such measures as input availability and prices and output prices, studies have been undertaken to model the effects of such changes. No disasters are obvious, though studies heavily depend on assumptions.

For the future, one of the strengths of the industry can be found in an increasing body of knowledge, not only on organic practices, but also on the effect of policies. Other strengths include the established standards and certification systems, and the existing market. Weaknesses or threats seem more numerous. The first is related to standards, including fraud, both by producers and certification agencies, and the possibility of accidents. The second is in the area of international trade, where the proliferation of standards and compliance schemes can make trade difficult for exporting countries. The desire of some countries to restrict international trade, and the absence of a scientific approach in some of the criteria are two more issues in the arena of international trade. Other threats concern consumer prices and governmental regulations. High consumer prices are a deterrent to growth in demand of organic products, and government regulations in one country cause a non-level playing field for producers in other countries.

References

Avery, D. 1995. *Saving the Planet with Pesticides and Plastics*. Hudson Institute, Indianapolis.

Butler, L. 2002. The economics of organic milk production in California: a comparison with conventional costs. *American Journal of Alternative Agriculture* 17(2): 83–91.

Clark, S., Klonsky, K., Livingston, P. and Temple, S. 1999. Crop-yield and economic comparisons of organic, low-input, and conventional farming systems in California's Sacramento Valley. *American Journal of Alternative Agriculture* 14(3): 109–121.

Commins, K. and Kung Wai, O. 2003. Regulations of imports into major markets. In: Westermayer, C. and Geier, B (eds.) *The Organic Guarantee System – The Need and Strategy for Harmonisation and Equivalence*. IFOAM/ FAO/ UNCTAD, Bonn. pp. 112–117.

Defra 2005. *Organic Food and Farming: Action Plan to Develop Organic Food and Farming in England*. Department for Environment, Food and Rural Affairs, London. http://www.defra.gov.uk/farm/organic/actionplan/actionplan.htm.

Delate, K., Duffy, M., Chase, C., Holste, A., Friedrich, H. and Wantate, N. 2003. An economic comparison of organic and conventional grain crops in a long-term agroecological research (LTAR) site in Iowa. *American Journal of Alternative Agriculture* 18(2): 59–69.

Deutsche Welle 2002. *Nitrogen Scandal Reveals Historical Traces*. Deutsche Welle, Bonn. http://www.dw-world.de/dw/article/0,1564,568009,00.html.

Dlouhy, J. and Nilsson, G. (eds.) 1983. *Comparisons between Farming Systems*. Swedish University of Agricultural Sciences, Uppsala.

EUROPA 2005. *European Action Plan for Organic Food and Farming*. European Commission, Brussels. http://europa.eu.int/comm/agriculture/qual/organic/plan/index_en.htm.

FAO 1998. Evaluating the potential contribution of organic agriculture to sustainability goals. *IFOAM Scientific Conference, Mar del Plata, Argentina, 16–19 November*. http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/003/AC116E/AC116E00.HTM.

Foster, C. and Lampkin, N. 1999. *European Organic Production Statistics*. University of Hohenheim, Stuttgart.

Halpin, D. and Brueckner, M. 2004. The retail pricing, labelling and promotion of organic food in Australia. In: DAFF. *The Australian Organic Industry: A Profile*. Department of Agriculture, Fisheries and Forestry (DAFF), Canberra. pp. 64–93.

Hamm, U., Gronefeld, F., Weinreich Hansen, M., Kristensen, N., Nielsen, T. 2004. *The Organic Food Market and Organic Marketing Initiatives in Europe: An Update Study*. Organic Marketing Initiatives and Rural Development (EC initiative), University of Wales Aberystwyth.

ITC 2005. *Market Development Section – Organic Products Home Page*. International Trade Centre, Geneva. http://www.intracen.org/mds/sectors/organic/welcome.htm.

Klepper, R., Lockeretz, W. Commoner, B., Gertler, M., Fast, S., O'Leary, D. and Blobaum, R. 1977. Economic performance and energy intensiveness on organic and conventional farms in the Corn Belt: a preliminary comparison. *American Journal of Agricultural Economics* 59(1): 1–12.

Kortbech-Olesen, R. 2006. *Demand for Organic Products from East Africa*. International Trade Centre (ITC), Geneva.

Lampkin. N. 1994. Estimating the impact of widespread conversion to organic farming on land use and physical output in the United Kingdom. In: Lampkin, N. and Padel, S. (eds) *The Economics of Organic Farming – An International Perspective*. CAB International, Wallingford. pp. 343–359.

Lampkin, N. and Padel, S. (eds) 1994. *The Economics of Organic Farming – An International Perspective*. CAB International, Wallingford.

Lockeretz, W. and Madden, P. 1987. Midwestern organic farming: a ten-year follow-up. *American Journal of Alternative Agriculture* 2(2): 57–63.

Lotter, D., Seidel, R. and Liebhardt, W. 2003. The performance of organic and conventional cropping systems in an extreme climate year. *American Journal of Alternative Agriculture* 18(3): 146–154.

Mäder, P., Fließbach, A., Dubois, D., Gunst, L., Fried, P. and Niggli, U. 2002. Soil fertility and biodiversity in organic farming. *Science* 296: 1694–1697.

Michelsen, J., Hamm, U., Wynen, E. and Roth, E. 1999. *The European Market for Organic Products: Growth and Development*. University of Hohenheim, Stuttgart.

Midmore, P. and Lampkin, N. 1994. Modelling the impact of widespread conversion to organic farming: an overview. In Lampkin, N. and Padel, S. (eds) *The Economics of Organic Farming – An International Perspective*. CAB International, Wallingford. pp. 371–380.

Murphy, M.C. 1975. *An Economic Appraisal of Organic Farming Systems*. Department of Land Economy, Cambridge.

Nicholas, P., Padel, S., Cuttle, S., Fowler, S., Hovi, M., Lampkin, N. and Weller, R. 2004. Organic dairy production: a review. *Biological Agriculture and Horticulture* 22(3): 117–149.

Nieberg, H. and Offermann, F. 2003. The profitability of organic farming in Europe. In: OECD (ed.) *Organic Agriculture: Sustainability, Markets and Policies*. CAB International, Wallingford. pp. 141–151.

Offermann, F. and Nieberg, H. 2000. *Economic Performance of Organic Farms in Europe*. University of Hohenheim, Stuttgart.

Organic Trade Association 2004. *The OTA 2004 Manufacturer Survey Overview*. Organic Trade Association, Greenfield. <http://www.ota.com/pics/documents/2004SurveyOverview.pdf>.

Pacini, C., Wossink, A., Giesen, G., Vazzana, C. and Huirne, R. 2003. Evaluation of sustainability of organic, integrated and conventional farming systems: a farm and field-scale analysis. *Agriculture, Ecosystems and Environment* 95(1): 273–288.

Padel, S. and Lampkin, N. 1994. Farm-level performance of organic farming systems: an overview. In Lampkin, N. and Padel, S. (eds) *The Economics of Organic Farming – An International Perspective*. CAB International, Wallingford. pp. 201–219.

Penfold, C., Miyan, M., Reeves, T. and Grierson, I. 1995. Biological farming for sustainable agricultural production. *Australian Journal of Experimental Agriculture* 35: 849–856.

Reganold, J. 1995. Soil quality and profitability of bio-dynamic and conventional farming systems: a review. *American Journal of Alternative Agriculture* 10(1): 36–45.

Scialabba, N. and Hattam C. (eds) 2002. *Organic Agriculture, Environment and Food Security* Food and Agriculture Organization of the United Nations, Rome.

Schmid, O. 2003. Comparison of EU Regulation 2092/91, Codex Alimentarius Guidelines for Organically Produced Food 1999/2001, and IFOAM Basic Standards 2000. In Westermayer, C. and Geier, B. (eds) *The Organic Guarantee System – The Need and Strategy for Harmonisation and Equivalence*. IFOAM/FAO/UNCTAD, Bonn. pp. 41–51.

Schou, J. and J. Streibig 1999. Pesticide taxes in Scandinavia. *Pesticide Outlook*. December 227–229.

Smith, E., Clapperton, M. and Blackshaw, R. 2004. Profitability and risk of organic production systems in the northern Great Plains. *American Journal of Alternative Agriculture* 19(3): 152–158.

Smolik, J., Dobbs, T. and Rickerl, D. 1995. The relative sustainability of alternative, conventional, and reduced-till farming systems. *American Journal of Alternative Agriculture* 10(1): 25–35.

Soil Association 2002. *Soil Association response to NFU survey of organic farmers*. Soil Association, Bristol. <www.soilassociation.org/sa/saweb.nsf/848d689047cb466780256a6b00298980/80256ad80055454980256c010045b622?OpenDocument>.

Stonehouse, P., Clark, A. and Ogini, A. 2001. Organic and conventional dairy farm comparisons in Ontario, Canada. *Biological Agriculture and Horticulture* 19(2): 115–126.

Tuson, J. and Lampkin, N. H. (eds.) 2006. *Organic farming policy measures in pre-2004 EU member states and Switzerland*. EU-CEE-OFP project report European Commission. University of Wales, Aberystwyth.

Vine, A. and Bateman D. 1981. *Organic Farming Systems in England and Wales: Practice, Performance and Implications*. Department of Agricultural Economics, University College of Wales, Aberystwyth.

Weir, M., Hansen, L., Andersen, L. and Millock, K. 2003. Consumer preferences for organic food. In: OECD (ed.) *Organic Agriculture: Sustainability, Markets and Policies*. CAB International, Wallingford. pp. 257–271.

Wynen, E. 1992. *Conversion to Organic Agriculture in Australia: Problems and Possibilities in the Cereal–Livestock Industry*. National Association for Sustainable Agriculture, Sydney.

Wynen, E. 1994. Economics of organic farming in Australia. In: Lampkin, N. and Padel. S. (eds) *The Economics of Organic Farming – An International Perspective*. CAB International, Wallingford. pp. 185–199.

Wynen. E. 1997. *Impact on Australian Broadacre Agriculture of Widespread Adoption of Organic Farming. Resource and Environmental Studies No. 14*. Centre of Resource and Environmental Studies, Australian National University, Canberra.

Wynen, E. 1998. *Organic Agriculture in Denmark – Economic Implications of a Widespread Change*. Danish Institute of Agricultural and Fisheries Economics, Copenhagen.

Wynen, E. 2002. *Bio-dynamic and Conventional Irrigated Dairy Farming in Australia: An Economic Analysis. Australasian Agribusiness Perspectives, Paper 50*. University of Melbourne, Carlton.

Wynen, E. 2001. The economics of organic cereal–livestock farming in Australia revisited. In: RIRDC (ed.) *The Organic Challenge: Unity through Diversity. RIRDC's Inaugural National Organics Conference 2001. Darling Harbour, Sydney, Australia, 27–28 August 2001.* Rural Industries Research and Development Corporation, Barton. pp. 89–100.

Wynen, E. 2003. *Organic Agriculture in Australia – Research Levies and Expenditures*. RIRDC, Barton.

Wynen, E. 2005. *Effects of Non-Harmonization on Production and Trade of Organic Products. Report for the International Task Force on Harmonization of Organic Standards and Certification*. IFOAM/FAO/UNCTAD, Bonn.

Wynen, E. and Edwards, G. 1990. Towards a comparison of conventional and chemical-free agriculture. *Australian Journal of Agricultural Economics* 34 (1): 39–55.

Chapter 11

Understanding the market for organic food

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Introduction

By 2002, the international market in organic foods and beverages was estimated to be worth US$23 billion (Sahota 2004). This brought the market share of certified organic food in the developed countries where it is predominantly consumed to somewhere between 1% and 2% of total food sales (Sligh and Christman 2003). According to critics, this small percentage proves organics to be little more than an overhyped Western food fad (see Lockie 2006). Yet with ongoing sales growth in developed countries of between 8% and 20%, organic foods have attracted the interest of a growing number of farmers, food processing firms, retailers and governments (Burch *et al*. 2001). Along with fair trade goods, organics has become one of the fastest growing sectors of a global food market characterised more generally by oversupply and falling terms of trade (McCoy and Parlevliet 2000, Raynolds 2000, Sligh and Christman 2003). Indeed, it has been estimated that the international market in organic foods could reach US$100 billion as early as 2006 (McCoy and Parlevliet 2000) with the organic sector in the United States of America (USA) alone worth over US$30 billion by 2007 (Haumann 2004). From an insignificant niche market as recently as the mid-1990s (Sahota 2004), organics has leapt into the mainstream.

This is not to say that this growth will continue indefinitely. The expansion of larger European markets appears to be slowing as they approach what some commentators refer to as 'maturity' (Sahota 2004). And as expansion slows, price premiums come under pressure, as reflected in a dramatic fall in the farm gate prices paid to organic dairy farmers in the United Kingdom (UK) in 2001 as a result of apparent oversupply (Franks 2003). In other markets, the issue appears to be less one of demand slowing than of producers failing to supply produce of sufficient consistency in quantity and quality to secure a sound distribution and retail base (Hassall and Associates 1990, Conacher and Conacher 1991, Hudson 1996, Dumaresq and Greene 1997, Baecke *et al*. 2002). This limits opportunities to sell certified organic produce as much as it reduces opportunities to purchase it! In fact, despite conditions of apparent undersupply, around 35% of certified organic produce grown in Australia is sold as conventional (Halpin 2004a) while 40% of organic beef and 25% of organic milk in Belgium is sold as conventional (Baecke *et al*. 2002). Compounding these demand and supply-side constraints on the continued expansion of the organic market is the simple issue that the organic industry knows little about who purchases its products or why they purchase them (Hassall and Associates 1990, Conacher and Conacher 1991, Hutchins and Greenhalgh 1995, Hudson 1996, Dumaresq and Greene 1997).

Common lore tells us that organic market growth has been rooted in an unlikely mix of fear and fashion. Many consumers, it is believed, have been attracted to organics by their dread of the imperceptible threats of industrial food production. The 'mad cow' crisis and other food scares have so tested consumer confidence in conventional food systems, and the institutions that regulate them, that assurances regarding the safety of genetically modified organisms, food irradiation and agricultural chemicals have fallen on deaf ears. Others, purportedly, have been attracted by the positioning of organics as a premium quality niche product. Substantially higher retail prices for organic foods have promoted a perception that they are consumed primarily by those wealthy enough to pay virtually any price to purchase what they believe to be tasty, safe or nutritious foods. There is certainly a grain of truth in these beliefs. However, research does show organic consumption to be somewhat more complicated.

In this chapter we examine the organic marketplace in terms of the changing dynamics of supply and demand; what is known about those who consume organic foods; what strategies have been set in place to recruit more people as organic food consumers; and constraints and opportunities for further expansion of the market for organic foods. In doing so, we will address, at least in part, one of the principal concerns that has arisen within the organic sector as a consequence of its growth; that is, the concern that expansion has come at the cost of the core values and practices on which organic agriculture was founded (see *Chapters 9, 14* and *Special topic 3*).

The demand for organic foods

There is a widespread perception that rapid growth in the organic market since the mid-1990s has been based more on an escalation of consumer demand than on an expansion of supply (Lyons 2001). This 'demand–pull' perspective on market growth is lent credence by the claims of several distributors, processors and retailers that they have experienced considerable difficulty sourcing enough certified produce to satisfy buyers, leading some to sponsor the conversion of conventional farmers to organic production (Lyons 2001, Halpin and Parkinson 2004). Yet, as we have seen, there already are signs that recent rates of market expansion are slowing. The question is, at what point do we consider the market for organic produce to have 'matured'; that is, to have reached an equilibrium of sorts between supply and demand that is likely to remain relatively steady for the short to medium term? Or, to put it more bluntly, how big will the organic market get?

Demand, however, is a difficult concept to quantify. There are few people who, when asked, will state categorically that they would not purchase organic foods under any circumstances. Surveys suggest that were organic foods to be made as widely available as conventional foods, almost all Western consumers would buy them at least some of the time (Lockie *et al.* 2002). And the lower any retail price premium is over outwardly similar conventional foods, not surprisingly, the more people express an interest in purchasing organic produce (Lockie and Donaghy 2004). The level of demand, therefore, for organic foods derives not only from the values, beliefs and socioeconomic status of food consumers, but on the relationship between these attributes and supply side issues such as quality, distribution and retail pricing. Levels of demand, even within markets that appeared to have reached maturity, may shift very rapidly in response to major changes in supply. Given these factors, demand is examined in this section, from the perspective of existing supply side dynamics, retail price premiums and consumers' stated willingness to pay for certified organic foods.

Generating an accurate picture of the international organic sector accurately is hampered by limited data availability and uniformity. Nevertheless, the most recent International Federation of Organic Agriculture Movements report suggests that of the US$23 billion global retail market for organic food and drink in 2002, North America accounted for US$11.75 billion, Europe US$10.5 billion, Japan US$350 million, Oceania US$200 million, Latin America US$100 million and the rest of Asia and the whole of Africa less than US$200 million (Sahota 2004). These figures reflected growth, in 2002, of about 12% in North America, 8% in Europe, and 15% to 20% in Australia (Sahota 2004). Following several years of growth of between 20% and 40%, the UK most exemplified the slowing of market expansion in those European countries with comparatively large organic markets (Sahota 2004). Importantly, if this thumbnail sketch of the international organic marketplace is compared with broad international patterns of organic production, there are some notable points of divergence. Of the roughly 24 million hectares managed worldwide for certified organic production in 2002, over 10 million were located in Australia, 5.8 million in Latin America, 5.5 million in Europe, 1.5 million in North America, 880,000 in Asia, and 320,000 in Africa (Yussefi 2004). Despite the spatial dominance in Australia and Latin America of semi-arid rangelands used for extensive cattle grazing (Yussefi 2004), it is strikingly apparent that the poor countries of Africa, Asia and South America are producing significant quantities of organic foods almost exclusively for sale in Europe and North America (Sligh and Christman 2003, Parrott and Kalibwani 2004, Willer and Yussefi 2004). The same is true within Europe, where Italy and Spain act mostly as exporters to Germany and the UK (Smith and Marsden 2003), which import around 50% and 65%, respectively, of their organic food needs (Sligh and Christman 2003, see also McCoy and Parlevliet 2000).

Average national retail price premiums for certified organic food have been reported at 20% to 30% in Austria, 10% to 15% in Germany, 10% to 100% in both the USA and UK, and 80% in Australia (Sligh and Christman 2003, Halpin and Brueckner 2004). Considerable variability also may be found both between commodities and within countries, with those products that are supplied in bulk, and widely distributed to consumers, tending to receive the smallest price premiums. This is the case for organic milk in both the EU, where retail premiums on milk are small to non-existent (Sligh and Christman 2003), and Australia, where they are about 35% (Halpin and Brueckner 2004). In Denmark, where consumers display the second highest rate of expenditure on organic foods in Europe after Switzerland (Willer and Richter 2004), retail price premiums are reported to be negligible. The general pattern, however, is of retail premiums remaining considerably higher than the 15% to 20% that most surveys suggest is acceptable to most Western consumers (Lampkin 1990, Burfield 1998, Pearson 2001, Lockie *et al.* 2002, QDPI 2003, Dabbert *et al.* 2004). Even if we adopt the suggestion of Dabbert *et al.* (2004) that a retail premium of 25% to 30% is acceptable to enough European consumers that retailers may realistically charge this much while still broadening their organic customer base, existing retail premiums would seem a significant limitation on the ultimate size of the organic market.

Before concluding, however, that retail price premiums alone will ensure that organics never grows beyond its status as a lucrative niche market, additional points need to be considered.

First, it is impossible to predict the impact that future events and technological developments will have on consumer trust, or distrust, in conventional food production and regulatory systems. Another ‘mad cow’ crisis may well see perceptions regarding the acceptability of different price premiums revised upwards. Conversely, serious organic food scares may challenge perceptions that organic foods offer a safe alternative.

Second, research in Australia by Donaghy *et al.* (2003) suggests it is not the percentage increase in the price of individual organic foods that is important to most consumers but the absolute price increase. In other words, most consumers may be willing to pay a higher premium, in percentage terms, for less expensive goods on the assumption that this will make little difference to their overall grocery bill. Similarly, Krystallis and Chryssohoidis (2005) found, in their survey of Greek consumers, that willingness to pay varied across product categories and was higher in relation to those foods that were purchased more frequently, that were seen to be of higher quality and safety, and that were underwritten by trustworthy certification schemes. Taken together, these suggest that the best way to maximise organic market share will be to reduce retail premiums on more expensive value-added items while improving the quality and supply of less expensive, but more frequently purchased, items for which higher premiums can be maintained. However, organic foods often are represented, positioned and priced as premium gourmet brands, a strategy that may limit overall levels of demand.

Third, changes in the retail structure of the organic industry are leading to major changes in the availability and cost of organic foods. While health food and specialist organic stores pioneered organic retailing, mainstream supermarkets now dominate the sector. This shift has contributed to lower retail price premiums and higher growth rates in the total market share of organic foods (Hamm *et al*. 2002). But it appears also, in places, to have contributed to downward pressure on the prices received by farmers (Smith and Marsden 2003). This is likely to create, as Smith and Marsden (2003) point out, pressure to increase efficiency and economies of scale within the production sector in ways that may be inconsistent with organic values and principles. Supermarket dominance is also likely to promote increased reliance on imports of organic food from lower cost production centres in Africa and South America (although producers in developing countries face substantial regulatory hurdles in exporting to lucrative Western markets, see *Chapter 9*).

Fourth, in light of evidence that retail price premiums in general are substantially higher than those premiums received by farmers (Hassall and Associates 1996, Smith and Marsden 2003), it seems less than surprising that alternative marketing strategies based on direct farmer to consumer sales are developing alongside supermarket interest in organics. These promise to lower the gap between farm gate and retail premiums and suggest a range of possibilities for the resolution of supply problems and expansion of demand. See *Marketing organic foods* for discussion of the importance of retail strategy to the marketing of organic foods.

In sum, while there are plenty of signs that demand for organic foods will not support indefinite growth given existing retail price premiums, there also is evidence that innovations in distribution and retailing, coupled with lower retail price premiums, may provide the basis for continued expansion well beyond existing levels of organic food consumption.

Why people do or do not consume organic foods

International research suggests that those attributes of organic products most likely to influence consumers are, from most to least important:

1 health (i.e. minimal artificial chemical residues in the product and high nutritional value);
2 environment (i.e. environmentally friendly production and processing);
3 taste;
4 animal welfare;
5 minimal processing;
6 novelty; and
7 fashion.

Conversely, those attributes most likely to limit consumption of organics are also identified (Beharrell and MacFie 1991, Davies *et al*. 1997, Latacz-Lohmann and Foster 1997, Klonsky and Tourte 1998, Magnusson *et al*. 2001, Makatouni 2001, Pearson 2001, 2002, Lockie *et al*. 2002) from most to least important:

1 high price;
2 limited availability;

3 scepticism about the credibility of product claims;
4 poor appearance;
5 non-awareness of organic; and
6 contentment with existing products.

According to Sahota (2004), the typical organic consumer is urban, well-educated, from a middle to high income household, and discerning in their food choices. Market researchers in the USA (Hartman and Wright 1999) posit a more differentiated mix of organic consumers that includes: a small group of passionate environmentalists; an older, wealthier group concerned mostly about their own health; a young group who profess environmental concern but who tend to act on that concern only when convenient; and a growing mainstream who care about the environment and are willing to engage in 'green consumption' as products become more accessible. Italian researchers Chinnici *et al.* (2002), however, differentiate organic consumers into the health conscious (the largest group), the curious (and open to more sales), the pragmatic (who are very concerned about higher prices) and the nostalgic (who associate organics with the tastes and authenticity of the past). Each of these claims seem to make sense in light of the high retail premiums paid for organic foods. But it is important not to dismiss organic consumption as the domain only of the rich and passionate. According to Hartman and Wright (1999), most people who have no immediate interest in green consumption are those who struggle for economic survival, an underclass of the unemployed, underemployed and underpaid. If this group of very poor are taken out of consideration for a moment, some 75% of consumers in the USA emerge as genuinely interested in purchasing organic foods.

The belief that food should be safe, nutritious, tasty and environmentally responsible is not radical or marginal, so it should come as no surprise that many food consumers in Western countries profess to consume at least some organic food, 40% in Australia (Lockie *et al.* 2002). Consequently, several studies from around the world have found that beyond the exclusion of the very poor there are few meaningful demographic differences in Western countries between those people who consume organic foods and those who do not (Davies *et al.* 1997, Cunningham 2001, Lockie *et al.* 2002). The most important dimension of demographic difference is not education or income, as suggested by Sahota (2004), but gender, with significantly more women than men claiming to purchase organic foods (Davies *et al.* 1997, Cunningham 2001, Lockie *et al.* 2002). According to Cunningham (2001), this may stem from the higher levels of responsibility taken by women for feeding children and other family members although, as noted by Lockie *et al.* (2004), such responsibility can also place pressure on women to prioritise convenience and price.

Although many Western consumers claim to consume organic foods, and many more profess the values that underpin organic agriculture, overall levels of organic food consumption remain only 1% to 2% of total food sales. This raises questions as to just how many people purchase a substantial proportion of their food as organic and what it is that differentiates these committed organic consumers from more occasional organic consumers? For Australia, Lockie *et al.* (2004) estimated that committed organic consumers, those who claimed to consume half or more of their diet as organic, accounted for about half of all certified organic food sales. This group were more motivated than were occasional organic consumers to source foods they believed were natural (i.e. free from artificial additives, unnecessary processing, genetic engineering, irradiation, pesticides, preservatives, animal growth hormones, antibiotics), environmentally friendly, supportive of animal welfare, and likely to make them feel good emotionally. These groups did not express fundamentally different food values. Even those who did not consume any organic foods claimed to be motivated in their food choices by health, environmental and animal welfare concerns. The difference among the groups was how strongly these motivations were expressed relative to price and convenience.

Lockie *et al*. (2004) also examined how the motivations behind food choice interacted to influence increasing levels of organic food consumption. They found the major direct influence on increasing rates of organic food consumption to be consumers' commitment to the consumption of foods they perceived to be natural. Women, and those responsible for household food provisioning, were far more likely than others to be motivated by this concern. This was followed by willingness to pay a premium for environmental values. The next most important factor directly influencing rates of organic consumption was the level of motivation towards the consumption of food that made the respondent feel good, physically and emotionally. Organic food was not only believed to taste and smell better, but also to evoke feelings of safety and tradition. Again, responsibility for household food provisioning and gender were the major determinants of consumers' level of motivation towards sensory and emotional appeal.

Marketing organic foods

One of the things that is truly remarkable about organic foods, given their status as one of the fastest growing sectors of the food industry, is how little their marketing depends either on consumer research or on aggressive advertising and discounting (Hill and Lynchehaun 2002). At face value, the 'demand–pull' perspective on organic sector growth would suggest that organic growers have been in the enviable position of being able to concentrate their energies on expanding their farming operations while receiving premium prices for their produce. Despite a paucity of organic food advertising in the mainstream media, that media portrays organics as the almost sole alternative to environmental and food safety risks associated with industrial agriculture (see Lockie 2006). Analysis of newspaper references to organic food and agriculture in the UK, USA and Australia suggests that the term 'organic' has come to signify a loosely defined bundle of desirable attributes related to quality, safety, ecology, tradition and provenance. In a world where regulatory agencies, and the complicated systems of quality assurance they administer, seem incapable of guaranteeing the safety of conventional foods, the organic label offers a simple, recognisable and, for some, comforting alternative (Lockie 2006). Unfortunately, for organic growers, organic produce does not necessarily 'walk off supermarket shelves'. That a significant proportion of certified organic produce is still sold on conventional markets demonstrates there is no guarantee that the use of organic methods will result in the sale of a clearly differentiated organic product. As a consequence, marketing efforts within the organic production sector have concentrated on the development of supply chains (i.e. on the development of distribution and retailing arrangements) (Latacz-Lohmann and Foster 1997, Baecke *et al*. 2002) and on the development of an appropriate regulatory regime to police usage of the term 'organic' (Guthman 2004).

The single most important strategy in the marketing of organic foods has been the establishment of regulatory systems to oversee the development of standards and inspection systems for organic production, processing and labelling (see *Chapter 9*). In terms of market expansion, independent third party certification of compliance with organic process standards achieves several things. Most obviously, certification provides some measure of guarantee for the buyer that they are getting what they pay for. As progress continues towards the harmonisation of standards on both national and international levels, buyers may extend their confidence to produce sourced from almost anywhere in the world. Further, even though no set of standards can be expected to codify adequately all the principles of organic agriculture, or all the conditions under which it might be practiced, compliance with these standards implies, nevertheless, an integrity that encourages consumers to associate several desirable attributes with certified organic foods even though, strictly speaking, those attributes fall outside the scope of what is guaranteed. Such attributes include taste, healthfulness, and so on. From the growers' perspective, independent certification enables those who have undertaken it to make claims that, in many circumstances, have clear value in the marketplace. The flipside to this is that the regulatory regimes underpinning certification preclude those who have not been certified from labelling their produce as organic.

Guthman (2004) argues that organic certification creates conditions of scarcity, by limiting the amount of food labelled as organic in the marketplace, and thus provides the basis for farm gate and retail price premiums. While notions of scarcity and price premiums intuitively would suggest that certification may limit market expansion, the effects may be both positive and negative. The cost and complexity of certification certainly does discriminate against smaller growers, particularly those in the developing world (see *Chapter 9*). However, scarcity and price premiums have acted to encourage those farmers and others who could afford the cost of certification into the organic sector and have thus helped to boost organic food supply and availability. This has been clearly demonstrated in the USA, where the implementation of a uniform national standard in 2002 is credited with boosting consumer awareness and confidence in organic produce and with clearing the way for its entry into mainstream supermarkets (Sahota 2004).

There are now few developed countries where mainstream supermarkets and other large retail chains do not appear set to dominate sales of organic foods. Among the world's three largest national organic markets, for example, supermarkets claimed 49% of organic retail sales in 2001–02 in the USA, 40% in Germany and 80% in the UK (Sligh and Christman 2003). Four years previously, the supermarket share of organic retail sales in Germany had been a mere 26% (Richter *et al.* 2001). In the USA, 31% of the organic retail market in 2001–02 was held by just three natural food retail chains (i.e. Whole Foods Market, Trader Joe's and Wild Oats Markets) that operated across multiple locations using store layouts and scales similar to those of conventional supermarkets (Sligh and Christman 2003). Reflecting the assumption, whether accurate or not, that organic consumers are urban, educated and comparatively wealthy, European supermarket chains have been shown to concentrate the availability of organic foods in larger, higher quality urban stores (La Via and Nucifora 2002).

The increasing involvement of very large businesses, such as supermarket chains, in the organic sector has attracted concern and criticism. The argument is that in relatively small-scale and localised food networks, enough opportunities are afforded to consumers for direct interaction with growers to ensure their confidence in the integrity of the foods they purchase. By replacing direct interaction, and the trust it encourages, with codified sets of standards, the way is cleared for organic foods to be shipped around the world at enormous cost in fossil fuels and at the expense of values that are not easily codified such as agricultural biodiversity and community building (see Guthman 2004). The 'conventionalisation thesis', as this has become known, assumes that the entry of larger businesses into the organic sector first displaces the smaller businesses that pioneered the sector and second, that these businesses do not share the values, nor implement organic standards with same authenticity, as organic pioneers.

There can be little doubt, however, that the increased visibility and availability of organic foods facilitated by mainstream supermarkets has been a major factor in expansion of the organic market (Richter *et al.* 2001). The reduced distribution costs and economies of scale enabled by the involvement of larger retailers have contributed to lower retail price premiums, and hence increased consumer demand, in those European countries where supermarkets dominate organic sales (Hamm *et al.* 2002). Further, because the total volume of organic food sales has increased alongside mainstream supermarket involvement in the industry, the increased market share captured by supermarkets has not come directly at the cost of absolute sales among their competitors (Richter *et al.* 2001). Indeed, where small retailers, such as health food stores, have experienced declining organic food sales they have done so less because of mainstream supermarket competition than because of competition from specialist organic and natural food chains (Richter *et al.* 2001).

The other area of growth in organic food retailing (in absolute if not relative terms) has been direct farmer to consumer sales. Farmers' markets, box schemes (i.e. local, not-for-profit groups buying and distributing organic food cooperatively), farm gate sales, community supported agriculture and other forms of direct selling accounted in 2002 for 20% of organic retail sales in Germany, 16% in Australia, and 10% in Austria and Denmark (Lockie *et al.* 2002, Sligh and Christman 2003). Similarly, direct sales accounted for 10% of all organic food sales in the UK in 2002–03 (Soil Association 2003). Even in the USA, where only 3% of organic retail sales were direct in 2001–02 (Sligh and Christman 2003), thousands of farms are now involved in community supported agriculture programs that encourage tens of thousands of consumers to subscribe for a weekly share of the season's harvest, whatever it may bring (Pretty 2002). In contrast with the downward pressure that mainstream retailer involvement in organics is likely to place, in the longer term, on farm gate premiums (Smith and Marsden 2003), direct sales offer practical ways for farmers to capture a greater share of the consumer dollar. The emphasis placed by direct sales strategies on personal interaction, localisation and seasonality makes them particularly well suited to smaller growers who struggle to offer the quantities and continuity of supply required by supermarkets. At the same time, the emphasis placed by direct sales on personal interaction, localisation and seasonality promotes a sense of integrity and credibility in the organic sector. Altogether, this suggests that the relationship between large retailer involvement in organics and direct farmer to consumer sales is not always an antagonistic one. It is true that many of the people whom engage in direct sales, either as buyers or sellers, probably do so out of a belief that buying organic food at a chain store is somehow counter to the principles of organics. But it is also true: first, that many people who prefer to buy direct when possible still appreciate the convenience and accessibility of major retail chains when it is not (Lockie 2002); second, that many involved in direct sales as consumers came to an awareness of organics through the appearance of organic foods in conventional retailers; and third, that many small to medium size farms engage in both direct and indirect sales in order to spread their marketing options and risk (Halpin 2004a).

The importance of large mainstream retailers and the visibility they lend to organics is underscored by the Richter *et al.* (2001) review of organic food marketing in Europe and the USA. The most important feature of those supermarket chains that reported success in their marketing of organic products, in terms of profitability and corporate image, was the in-store visibility of organic products. This visibility was underscored by the range of organic products available, the availability of promotional and educational material within the store, and knowledgeable sales people. These chains took active steps to ensure that, wherever possible, every major product grouping included a high quality organic option by appointing dedicated senior management personnel and by working with suppliers. The leading chains in organic sales had been involved in the sector since before demand for organic products mushroomed in the late 1990s (suggesting they were key players in this escalation of demand), had detailed environmental management policies and strategies that extended beyond the sale of organic foods to include matters such as energy conservation (see also Burch *et al.* 2001), and featured organics prominently in their advertising. Those chains less committed to organics tended to stock a limited range of long shelf-life dry goods. Almost all chains used their own organic certification labels to reduce confusion, although few collected data on who was buying their organic products or why. Consequently, there were few attempts to target the specific needs of different consumer groups. There was a general concentration on information related to health and food safety as well as, to a lesser extent, environment, taste and animal welfare (see also Hamm *et al.* 2002).

Expanding the 'market' for organic foods

The foregoing discussion has highlighted options for promoting continued expansion in the organic market. Consumer surveys from around the world consistently indicate both that most Western consumers are positively disposed towards organic foods and that the major barriers to their increased consumption of those foods are perceived to be their price and availability. The experience of major retailers in Europe is consistent with these claims (Richter *et al.* 2001). Those countries with comparatively more mainstream retailer involvement in the organic sector and/or lower retail premiums tend to have higher per capita levels of organic food consumption. At the same time, those retailers that report the most corporate benefit from organic sales are those that offer a comprehensive choice of easily identifiable organic product lines. Consumer research also highlights the importance of credibility and trust (see Lockie *et al.* 2002), matters that increasingly are addressed though the implementation of strictly regulated standards setting and inspection regimes.

We have no wish to imply here that all organic producers or processors need to do is get a certified product to market and it will sell itself. Although there is insufficient space here to discuss the issue fully, we suggest that one of the characteristics common to many growers, processors and retailers who have successfully expanded their sales is the considerable effort they have put into a supply chain organisation (see Halpin 2004b). The key point is that resolving the supply side issues necessary to promote market expansion involves more than simply expanding production or putting more product lines on the shelf. For supermarkets that trade on convenience and choice, the focus of coordination is on securing supplies of consistent quality and quantity across a diverse product range. Strategies to achieve this range from supporting the conversion of conventional enterprises to organic production and processing, to encourage the pooling of produce from smaller farms into larger consignments, and importing supplies from elsewhere. Even farmers' markets, community supported agriculture and box schemes that trade on seasonality, locality and community may be seen as methods to introduce convenience and choice to the realm of direct sales by making it easier for consumers to access a wider range of produce. Organisers of such schemes often supply recipes and other information to help consumers cope with the 'inconvenience' of seasonal gluts and shortages and with unfamiliar produce.

As important as supply chain organisation and standards regulation are to the organic market, we cannot overlook the questions of how organic foods are promoted and to whom. Organic foods are consumed in at least small quantities by enough Western consumers that there is little to differentiate between those who do eat organic food and those who do not (Pearson 2002). The values that underpin organic food and agriculture, environmental sustainability, food safety and nutrition, animal welfare and so on, are widely perceived as important (Lockie *et al.* 2002). Nevertheless, the most committed consumers of organic food are those who place a high value on the perceived 'naturalness' of food (Lockie *et al.* 2004). These are more likely to be women than men, and more likely than not to take major responsibility for food shopping and preparation within their household. This group do not need to be convinced of the merits of organic foods. Further, even though the demands placed on their time by responsibility for food provisioning lead this group to place a high value on convenience (Lockie *et al.* 2004), this is the group most likely to actively seek out organic foods and to adapt their shopping behaviour accordingly. In doing so, members of this group may challenge the idea that large supermarkets are as convenient as they are widely perceived to be and the notion that taking time to think about food is an inconvenience (Lockie 2002). In promoting organic foods to this group, the key attributes are naturalness and authenticity. They are uncomfortable with highly processed organic foods and long-distance transportation and would rather know where they can buy fresh local produce and minimally processed dry goods.

Most organic food consumers are not, of course, so committed. They do not change their shopping habits readily and will substitute conventional products for organic whenever the latter are not available or affordable at their regular shopping outlets. Nevertheless, increasing sales to this group may represent one of the easier growth paths for the organic industry. These buyers do not need to be convinced of the merits of organic food. They already purchase it. All that needs to be done is to convince them to purchase more of it. In order to promote organic products to this group the organic industry needs to address a range of issues including:

1 Pricing: retail price premiums remain considerably higher in most national markets than most consumers are willing to pay. Addressing this will remove a major barrier to organic food sales among less committed consumers.
2 Visibility: most food purchasing decisions are based on habit (Pearson 2000). Varying habitual patterns and developing new shopping habits is strongly influenced by the visibility of alternatives. Although introducing organic foods to major retail chains certainly has increased their visibility, the appearance and layout of product displays also is critical. The most influential area to display products is where buyers enter the retail outlet, at the ends of aisles, and/or at eye level. Even where this is not possible, it is important that displays identify organic products in some prominent manner.
3 Labelling: as well as reducing the visibility of organic foods, inconsistent and inadequate labelling reduces consumer confidence and trust in the integrity of organic claims (Lockie *et al.* 2002). National and international harmonisation or certified organic labels would be welcomed by most consumers if not by the certifying bodies who compete for farmers' business.
4 Availability: the supply and quality of organic products must be consistent enough that buyers are not tempted to substitute them for conventional products. There may be circumstances in which the organic industry is better served by a strategy of targeting a few key products than by attempting to provide a complete product range. Research has shown, for example, that a few fresh fruit and vegetables account for most of the expenditure, suggesting that the organic industry could have the greatest impact on its overall sales by targeting the top-selling items (Pearson 2000).

As stated above, there are relatively few Western consumers who state that they would not, under any circumstances, buy organic food. The barriers raised against organic consumption by members of this group typically focus, again, on pricing and availability (Pearson 2002). This group is clearly the least likely to bypass major retailers and make use of specialty food stores, home delivery services and so on. Given this, an obvious strategy to encourage members of this group to purchase organic foods is to sell them at the same price as conventional foods. At least one British supermarket chain has done this (selling some organic products at below cost) in order to increase the profile of its concern for the environment (Hutchins and Greenhalgh 1995). However, it is likely also that many strictly conventional food consumers see little intrinsic value in the organic label and are unlikely to purchase any organic food that does not possess the same visible quality attributes as conventional competitors (e.g. visual appearance, smell) even if it is no more expensive. This suggests that it is necessary to promote to this group the benefits of organic products, a strategy that may encourage them to accept a higher price because they believe that the positive attributes of organic products such as health, taste and environmental sustainability increase its value.

Conclusion

We have deliberately avoided offering a firm conclusion on just how big the organic market will grow. Slowing rates of expansion in Europe may suggest that projections the organic market could reach US$100 billion by 2006 are unduly optimistic, and that global demand for organic foods may plateau well before we reach this mark. However, few have so far tried to assess the implications of growing middle classes outside the developed economies of Europe, North America, Japan and Australia/New Zealand. Further, there is considerable scope still through adaptations in production, distribution and retailing strategies, and through the manipulation of retail price premiums, to influence demand in the West. The organic industry needs to at some point confront the question as to whether it wants to grow beyond a market share that enables it to be dismissed as a niche market and whether it is prepared to take the steps necessary to support higher levels of demand. For some, legitimately, the answer will be no. For others, there will be no question that if environmentally sound agricultural practices are to become the norm there is no choice but to promote aggressive expansion in the organic sector. However, it cannot be taken for granted that the spectacular growth we have seen in the organic market over the last decade will continue indefinitely. Neither can it be taken for granted that the strategies which have underpinned that growth to date will be sufficient even to ensure the social and economic sustainability of the organic sector as it now stands.

The most obvious way to increase demand for organic foods is to lower retail price premiums. Improving the visibility, availability and labelling of organic foods also carries considerable potential. Achieving these will depend not just on an expansion of production but on the organisation of a range of supply chain arrangements to move organic foods from the field to the point of sale as clearly differentiated products. Some of these arrangements will be highly integrated national and international networks. Others will be highly localised and, at times, informal. We have argued that while concern regarding the potential loss of key organic values and principles alongside market expansion is justified, the entry of mainstream retailers and other businesses into the organic sector has created opportunities for smaller enterprises and supply chains. This may not always be the case, but presently it appears that the increased market share of large retailers has come from the higher demand they have stimulated and not from the transfer of sales from elsewhere.

In closing, we would reiterate the point that underlies concern about ‘conventionalisation’; that is, that organic foods must retain their integrity and authenticity if they are to maintain any economic value (Latacz-Lohmann and Foster 1997). Although only loosely defined, the concepts of integrity and authenticity have enabled organic foods to signify a variety of often intangible attributes related to quality, safety, ecology, tradition and provenance. These perceptions have provided the organic industry with the free advertising that has afforded its status as the main alternative to industrial agriculture and emphasised all the risks and uncertainties with which mainstream production is attributed. If the market for organic food is to continue to grow, it must continue to offer, from standards to supermarket shelves to farmers’ markets, the taste, smell and texture of authenticity.

References

Baecke, E., Rogiers, G., De Cock, L. and Van Huylenbroeck, G. 2002. The supply chain and conversion to organic farming in Belgium or the story of the egg and the chicken. *British Food Journal* 104(3–5): 163–174.

Beharrell, B. and MacFie, J. 1991. Consumer attitudes to organic foods. *British Food Journal* 93: 25–30.

Burch, D., Lyons, K. and Lawrence, G. 2001. What do we mean by 'green'? Consumers, agriculture and the food industry. In: Lockie, S. and Pritchard, B. (eds) *Consuming Foods, Sustaining Environments*. Australian Academic Press, Brisbane. pp. 33–46.

Burfield, T. 1998. Organic impact. In: *Healthy Lifestyles (a supplement to Produce Merchandising)*. Vance Publishing, Lincolnshire. pp. H3–H6.

Chinnici, G., D'Amico, M. and Pecorino, B. 2002. A multivariate statistical analysis of the consumers of organic products. *British Food Journal* 104(3–5): 187–199.

Conacher, J. and Conacher, A. 1991. An update on organic farming and the development of the organic industry in Australia. *Biological Agriculture and Horticulture* 8: 1–16.

Cunningham, R. 2001. *The Organic Consumer Profile: Not Only Who You Think it is!* Strategic Information Services Unit, Agriculture, Food and Rural Development, Alberta.

Dabbert, S, Häring, AM and Zanoli, R. 2004. *Organic Farming – Policies and Prospects*. Zed Books, London.

Davies, A., Titterington, A. and Cochrane, C. 1997. Who buys organic food? A profile of the purchasers of organic food in Northern Ireland. *British Food Journal* 97: 17–23.

Donaghy, P., Rolfe, J. and Bennet, J. 2003. Consumer demands for organic and genetically modified foods. In: *47th Annual Conference of the Australian Agricultural and Resource Economics Society, 12–14 February 2003, Fremantle, Western Australia*. Australian Agricultural and Resource Economics Society, Perth.

Dumaresq, D. and Greene, R. 1997. *From Farmer to Consumer: The Future of Organic Agriculture in Australia*. Rural Industries Research and Development Corporation, Canberra.

Franks, J. 2003. Current issues in marketing organic milk in the UK. *British Food Journal*. 105(6–7): 350–363.

Guthman, J. 2004. *Agrarian Dreams. The Paradox of Organic Farming in California*. University of California Press, Berkeley.

Halpin, D. 2004a. A farm level view of the Australian organic industry. In: Halpin, D. (ed.) *Australian Organic Industry Profile*. Department of Agriculture, Fisheries and Forestry, Canberra. pp. 1–29.

Halpin, D. 2004b. Organic food supply chain relations and collaborative marketing. In: Halpin, D. (ed.) *Australian Organic Industry Profile*. Department of Agriculture, Fisheries and Forestry, Canberra. pp. 30–46.

Halpin, D. and Brueckner, M. 2004. The retail pricing, labelling and promotion of organic food in Australia. In: Halpin, D. (ed.) *Australian Organic Industry Profile*. Department of Agriculture, Fisheries and Forestry, Canberra. pp. 64–93.

Halpin, D. and Parkinson, J. 2004. Beyond the farm gate: the perspectives of processors, wholesalers and distributors in the organic industry. In: Halpin, D. (ed.) *Australian Organic Industry Profile*. Department of Agriculture, Fisheries and Forestry, Canberra. pp. 47–63.

Hamm, U., Gronefeld, F. and Halpin, D. 2002. *Analysis of the European Market for Organic Food*. University of Wales, Aberystwyth.

Hartman, H. and Wright, D. 1999. *Marketing to the New Wellness Consumer: Understanding Trends in Wellness*. The Hartman Group, Washington.

Hassall and Associates 1990. *The Market for Australian Produced Organic Food*. Rural Industries Research and Development Corporation, Canberra.

Haumann, B. 2004. United States. In: Willer, H. and Yussefi, M. (eds) *The World of Organic Agriculture: Statistics and Emerging Trends*. International Federation of Organic Agriculture Movements, Bonn. pp. 150–159.

Hill, H. and Lynchehaun, F. 2002. Organic milk: attitudes and consumption patterns. *British Food Journal* 104(7): 526–542.

Hudson. R. 1996. *The Domestic Market for Australian Organic Produce – an Update*. Rural Industries Research and Development Corporation, Canberra.

Hutchins, R. and Greenhalgh, L. 1995. Organic confusion: sustaining competitive advantage. *Nutrition and Food Science* November/December: 11–14.

Klonsky, K. and Tourte, L. 1998. Organic agricultural production in the United States: Debates and directions, *American Journal of Agricultural Economics* 80: 1119–1124.

Krystallis, A. and Chryssohoidis, G. 2005. Consumers' willingness to pay for organic food: factors that affect it and variation per organic product type. *British Food Journal* 107(5): 320–343.

La Via, G. and Nucifora, A. 2002. The determinants of the price mark-up for organic fruit and vegetable products in the European Union. *British Food Journal* 104(3–5): 319–336.

Lampkin, N. 1990. *Organic Farming*. Farming Press, Ipswich.

Latacz-Lohmann, U. and Foster, C. 1997. From 'niche' to 'mainstream' – strategies for marketing food in Germany and the UK. *British Food Journal* 99: 275–282.

Lockie, S. 2002. 'The invisible mouth': mobilizing 'the consumer' in food production-consumption networks'. *Sociologia Ruralis* 42(4): 278–294.

Lockie, S. 2006. Capturing the sustainability agenda: organic foods and media discourses on food scares, environment, genetic engineering and health. *Agriculture and Human Values*. (In press.)

Lockie, S. and Donaghy, P. 2004. Who consumes organic foods in Australia. In: Halpin, D. (ed.) *Australian Organic Industry Profile*. Department of Agriculture, Fisheries and Forestry, Canberra. pp. 94–105.

Lockie, S., Lyons, K., Lawrence, G. and Mummery, K. 2002. Eating green: motivations behind organic food consumption in Australia. *Sociologia Ruralis* 42(1): 20–37.

Lockie, S., Lyons, K., Lawrence, G. and Grice, J. 2004. Choosing organics: a path analysis of factors underlying the selection of organic food among Australian consumers. *Appetite* 43: 135–146.

Lyons, K. 2001. From sandals to suits: green consumers and the institutionalisation of organic agriculture. In: Lockie, S. and Pritchard, B. (eds) *Consuming Foods, Sustaining Environments*. Australian Academic Press, Brisbane. pp. 82–94.

Magnusson, M., Arvola, A., Koivisto Hursti, U., Aberg, L. and Sjoden, P. 2001. Attitudes towards organic foods among Swedish consumers. *British Food Journal* 103: 209–26.

Makatouni, A. 2001. What motivates consumers to buy organic food in the UK? Results from a qualitative study. *organic-research.com* 1: 1–11.

McCoy, S. and Parlevliet, G. 2000. *Export Market Potential for Clean and Organic Agricultural Products*. Rural Industries Research and Development Corporation, Canberra.

Parrott, N. and Kalibwani, F. 2004. Africa. In: Willer, H. and Yussefi, M. (eds) *The World of Organic Agriculture: Statistics and Emerging Trends*. International Federation of Organic Agriculture Movements, Bonn. pp. 55–63.

Pearson, D. 2000. Fresh fruits and vegetables: what we buy and why? *Food Australia* 52: 306–308.

Pearson, D. 2001. How to increase organic food sales: results from research based on market segmentation and product attributes. *Australian Agribusiness Review* 9: 1–8.

Pearson, D. 2002. Marketing organic food: who buys it and what do they purchase? *Food Australia* 54: 31–34.

Pretty, J. 2002. *Agri-Culture: Reconnecting People, Land and Nature*. Earthscan, London.

QDPI 2003. *Drivers of Consumer Behaviour. Organic Food*. Queensland Department of Primary Industries, Brisbane. <http://www.dpi.qld.gov.au/businessservices/11480.html>. Accessed 21/8/05.

Raynolds, L.T. 2000. Re-embedding global agriculture: the international organic and fair trade movements. *Agriculture and Human Values* 17: 297–309.

Richter, T., Schmid, O., Meier, U., Halpin, D., van den Berge, P. and Damary, P. 2001. *Marketing Approaches for Organic Products in Supermarkets: Case Studies from Western Europe and the United States of America Conducted in 2000*. Research Institute of Organic Agriculture, Ackerstrasse.

Sahota, A. 2004. Overview of the global market for organic food and drink. In: Willer, H. and Yussefi, M. (eds) *The World of Organic Agriculture: Statistics and Emerging Trends*. International Federation of Organic Agriculture Movements, Bonn. pp. 21–26.

Sligh, M. and Christman, C. 2003. *Who Owns Organic? The Global Status, Prospects and Challenges of a Changing Organic Market*. Rural Advancement Foundation International-USA, Pittsboro.

Smith, E. and Marsden, T. 2003. *Exploring the 'Limits to Growth' in UK Organics: Beyond the Statistical Image*. The Centre for Business Relationships, Accountability, Sustainability and Society, Cardiff University, Cardiff.

Soil Association 2003. *Organic Food and Farming Report 2003*. Soil Association, Bristol.

Thompson, G. 1998. Consumer demand for organic foods: what we know and what we need to know. *American Journal of Agricultural Economics* 80: 1113–1118.

Willer, H. and Richter, T. 2004. Europe. In: Willer, H. and Yussefi, M. (eds) *The World of Organic Agriculture: Statistics and Emerging Trends*. International Federation of Organic Agriculture Movements, Bonn. pp. 93–117.

Willer, H. and Yussefi, M. (eds) 2004. *The World of Organic Agriculture: Statistics and Emerging Trends*. International Federation of Organic Agriculture Movements, Bonn.

Yussefi, M. 2004. Development and state of organic agriculture worldwide. In: Willer, H. and Yussefi, M. (eds) *The World of Organic Agriculture: Statistics and Emerging Trends*. International Federation of Organic Agriculture Movements, Bonn. pp. 13–20.

Chapter 12

Environmental impacts of organic farming

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Introduction

A high proportion of the Earth's land surface has been transformed by direct human action, with significant consequences for biodiversity, nutrient cycling, soil structure and biology, and climate. Agriculturally used land accounts for 38% of the world's total land area, of which 69% is permanent pasture, making it the leading type of *agricultural land use*; 28% is arable land and 3% is under permanent crops (FAO 2004).

The location and physical production conditions are important determinants of the types and intensities of agricultural land use; in particular, the management of relatively flat, fertile land has often been progressively intensified, with mechanisation leading to increased field sizes, removal of boundary vegetation and increased application of agrochemicals. In contrast, traditional farming systems on marginal land, where possibilities for mechanisation are limited because of steep or inaccessible terrain, are in many areas under considerable economic pressure or have been abandoned already.

The term 'organic agriculture' used in this chapter is based on the Codex definition of the FAO (1999, see *Chapter 1*). According to Parrott and Marsden (2002) organic agriculture, which relies on natural methods of building soil fertility and controlling pests and diseases, can be divided into two categories: certified organic farming and *de facto* organic farming. Whereas certified organic production is often oriented towards the market for food labelled as organic, the latter may represent the major part of organically managed land. Such *de facto* organic farming can often be found in resource-poor and/or agriculturally marginal regions where local populations have a limited engagement with the cash economy. This includes many traditional farming systems found in developing countries, which have evolved through centuries to create agricultural systems adapted to local environmental and cultural conditions (Parrott and Marsden 2002; Scialabba and Hattam 2002). This chapter covers the environmental impacts of organic farming in this wider sense and also includes agroforestry, a management system that integrates trees in the agricultural landscape and that is systematically applied in organic agriculture. Agroforestry is practiced in all agroclimatic zones but is most prevalent in the tropical belt (Kotschi and Müller-Sämann 2004).

Organic agriculture is generally perceived as a form of agriculture that is more favourable for the environment than conventional agriculture. In this chapter it is asked where, precisely, the differences are in environmental terms and whether the available empirical evidence allows for a generalisation. Geographical differences and interrelationships are emphasised wherever

Table 12.1 Overview of the main fields of environmental impact examined and the specific aspects covered (after OECD 1997)

Area	Aspect/indicator
Biodiversity	Genetic diversity
	Floral diversity
	Faunal diversity
	Habitat diversity
Landscape	Landscape structures and aesthetic value
Soil	Soil organic matter (SOM) and acidity (pH value)
	Biological activity
	Soil structure
	Erosion
	Desertification
Ground and surface water	Nutrient use and balance
	Nitrate leaching
	Phosphorus
	Pesticides
	Pathogens
Climate and air	Carbon dioxide (CO_2)
	Nitrous oxide (N_2O)
	Methane (CH_4)
	Ammonia (NH_3)
Energy	Intensity of energy use
	Efficiency of energy use

relevant. Primary sources for this chapter are a review of research results, mainly for developed countries in temperate and subtropical zones. There is a lack of scientific research in developing countries in the tropics and subtropics, but from practical experiences and case studies, it may be assumed that results are transferable (Alföldi *et al*. 2002).

A wide range of indicators are being used in the description of the environmental impacts of agriculture. Particularly, the Organisation for Economic Cooperation and Development (OECD) pushes the development of a common set of indicators at an international level. The assessment presented here is based on the Driver–State–Response (DSR) framework that has been developed by the OECD in (OECD 1997). This framework is internationally accepted and allows cross-country comparisons. Whenever appropriate, simplifications and modifications have been made.

The main indicators used in the analysis presented in this chapter are given in Table 12.1. The discussion of environmental impacts is structured by six main sectors. There are significant interrelationships between these sectors.

Biodiversity

Since its beginnings, agriculture has been a source of positive and negative effects on the ecosystem in terms of wildlife conservation and landscape. The level of intensity that modern agriculture has reached in wide areas of Europe has resulted in a decrease in biological diversity of domestic and wildlife species. The destruction of biotopes, as well as the simplifications of crop rotations, and the increasing input of synthetic fertilisers and pesticides has been responsible for changes in the habitat of many species.

Maintaining and enhancing biodiversity is considered central to developing a sustainable organic system. Organic farming depends upon stabilising agroecosystems, maintaining ecological balances, developing biological processes to their optimum and linking agricultural activities with the conservation of biodiversity (Alföldi *et al.* 2002). Increased biodiversity improves and buffers ecological services such as pollination, pest control, maintenance of soil fertility, thus strengthening farming systems and practices. Building on that, some organic certification organisations have incorporated biodiversity requirements into their standards (Alföldi *et al.* 2002). The Swiss organic standards, for example, require farmers to use 7% of their land as semi-natural habitats (Bio Suisse 2001).

Tybirk *et al.* (2004) state that organic farming systems seem to be an appropriate tool for planners to balance conservation and production, but the philosophy behind 'the more biodiversity the better' requires a deeper discussion. Many researchers have claimed that processes and functional groups of organisms are more important for ecosystem function than 'just' maximising the diversity (e.g. Kareiva 1994, Tilmann 1997, Hodgson *et al.* 1998).

In a review of 76 studies that explicitly compared the effects on biodiversity of organic farming relative to conventional agriculture, Hole *et al.* (2004) highlighted three broad management practices that are largely intrinsic to organic farming (but not exclusive), and particularly favour farmland wildlife: a ban or a reduced use of chemical pesticides and inorganic fertilisers, sympathetic management of non-cropped habitats, and preservation of mixed farming.

While comparing the impacts of organic and conventional farming systems on biodiversity, Hole *et al.* (2004) identified the following problems:

- variation in the definition of organic farming standards between countries;
- disparity between studies in their control for extraneous variation;
- variation in the period the studies were carried out;
- variation in the spatial scale; and
- use of different 'measures' of biodiversity.

Furthermore, there are several factors that may result in underestimating the benefits of organic farming on biodiversity, such as a possible time lag in the response of wildlife communities after switching from conventional to organic farming, or the difficulty in detecting significant effects at the field scale for mobile taxa such as birds and butterflies.

Nevertheless, most studies reviewed clearly demonstrate that species abundance and/ or richness across a wide range of taxa tend to be higher on organic farms than on locally representative conventional farms. This particularly applies to species which have experienced declines in range and/or abundance as a consequence of past agricultural intensification.

The effects on biological diversity are reviewed in more detail for the following three aspects: genetic diversity, species diversity (floral and faunal) and habitat diversity.

Genetic diversity

Today, the adoption of high yielding, uniform breeds and varieties has led to a considerable reduction in the number of species and in the number of varieties/breeds within species used in agriculture (Alföldi *et al.* 2002). There are many schemes and projects worldwide working to conserve seed banks and indigenous varieties, many of which are linked to organic agriculture projects (Stolton 2002). A typical example is the Sustainable Agriculture and Rural Development Project (SARDI) in Kenya where a community indigenous seed conservation program is being implemented. Indigenous seeds have been shown to perform better in drought conditions

(Waireg 2000, reported in Stolton 2002). Another example is given by Vreeland (2000) who reports on Indians in the High Jungle of Peru who organically cultivated cotton and thereby conserved ecotypes adapted to the moist tropical conditions. Vreeland emphasises that native cotton can also provide valuable genetic materials for improving commercial cotton varieties because of the high degree of natural resistance to insects, disease and drought stress.

Even though there is evidence that organic farming systems are more likely to use rare, native or traditional breeds, there are only few studies that investigate the role of organic livestock in maintaining the genetic diversity of domesticated stock (Bremond 2002).

Since 1995, organic agriculture has indirectly established a rescue process for species, varieties and breeds threatened by underuse or extinction. As demonstrated in various case studies, organic agriculture, almost without the help of governmental institutions, is providing an important contribution to the *in situ* conservation, restoration and maintenance of agricultural biodiversity (Scialabba *et al.* 2002).

A possible future threat to genetic diversity and biodiversity in general, could be the side effects of the release of genetically engineered or modified organisms (GMOs) into the environment (Soil Association 2001). In organic agriculture genetic engineering is banned (Alföldi *et al.* 2002).

Floral diversity

In general, the diversity of floral species is closely connected to local site conditions. Nevertheless, Hole *et al.* (2004), while investigating the flora of arable and mixed farming, recorded higher weed abundance and species richness in fields under organic management in almost all studies. In several studies, organically managed fields held considerably rarer and/or declining species. However, in regions with low potential for biodiversity, the positive impact of organic farming on wild herb or grassland diversity is less distinct (Baars *et al.* 1983, Smeding 1992).

Factors that contribute to greater floral diversity include the proportion of grassland relative to arable cropping, the variation in sowing dates for cereal crops and the inclusion of both autumn-sown and spring-sown cereals. A richer floral diversity has positive impacts on faunal diversity, because it offers overwintering sites, refuges and areas with network links to other habitats (Shepherd *et al.* 2003). Weeds are considered competitive to the crop in conventional farming and are eliminated by herbicides, whereas in organic systems, some of the accompanying plants are desired to a certain degree and are considered useful as they provide ecological services (Alföldi *et al.* 2002). In the context of pollinators, which greatly benefit from a diversity of flowers, flowering weeds are more diverse and abundant in organic arable fields and grassland compared to conventional fields (Frieben and Köpke 1996). In organic grassland, the average number of species was higher than in conventional, as a result of lower stocking rates and lower fertilisation levels in organic farms. Additionally, the mowing date is often delayed, which means that grass species can reach the flowering stage and thus achieve greater reproduction, leading to plant communities rich in species and structure (Frieben and Köpke 1996, Frieben 1997).

Van Mansvelt *et al.* (1998) compared 7 organic and 8 adjacent conventional farms in the Netherlands, Germany and Sweden in order to evaluate their effect on landscape diversity. They found the farmland area dedicated to natural elements ranged from 55% to 20% in the mixed organic farms and from 11% to 0.3% in the conventional neighbours. A study by Aude *et al.* (2004) compared the conservation value of hedge bottom vegetation on organic and conventional farms in Denmark. The hedgerows studied (28 organic, 28 conventional hedgerows) were established in the same way except that the organic hedgerows were managed without pesticides. Significantly more plant species were found in the organic hedgerows and their species composition appeared similar to semi-natural plant communities.

The biological relationship between floral diversity and both pest and beneficial insects has been studied extensively. The importance of flowers to attract beneficial insects for adult feeding as well as grass banks as overwintering sites for predatory beetles is now fully recognised (Van Emden 2003). Uncultivated land, hedgerows inside crops, in allied crops and in neighbouring areas can serve as refugia for beneficial insects such as parasitoids of aphids (Verkerk *et al.* 1998). The data generated by Langer (2001) was based on an organically farmed experimental system, and indicated that short rotation coppice hedges and clover/grass leys in the rotation may increase diversity and activity of parasitoids attacking cereal aphids. Besides the positive effects of biological pest control, from a farmer's point of view, negative interactions such as pests overwintering in hedges and weeds invading from field margins are also important. Many farmers considering converting to organic farming fear that such problems will be very difficult to manage. Although some mechanisms of natural enemy enhancement, such as increasing diversity within cropping systems, have been explained in specific systems, it is difficult to show universal trends due to the great diversity of systems and competing processes that vary under different conditions (Verkerk *et al.* 1998, Tybirk *et al.* 2004).

Concerning domesticated species, organic farming aims for a greater diversity of crops in their rotation. Wide crop rotations are essential as a means of disease and pest prevention. They also contribute to maintaining soil fertility, particularly if N-fixing legumes are part of the rotation. While organic farming standards recommend cultivating site-adapted crop varieties, organic farmers (just like their conventional colleagues) often choose modern high-yielding varieties. Nevertheless, the preservation of old land varieties and breeds is an important initiative within the organic farming movement (Stolze *et al.* 2000).

Faunal diversity

The effects of organic farming on faunal biodiversity have been studied, particularly for soil fauna and birds. In most cases, organic farming displays a greater faunal biodiversity than conventional farming. Key factors are: greater fauna-friendly crop protection management, the organic fertilisation regimes, the more diversified crop rotation, and the more structured landscapes with semi-natural habitats and field margins (Stolze *et al.* 2000, Alföldi *et al.* 2002). Landscape structures are essential for the survival of many invertebrates, especially due to favourable food and overwintering conditions. They also function as habitat crosslinks between meadows, fallows and field margins.

An analysis of some specific groups of fauna illustrates the interrelationships.

Earthworms

Earthworm populations can indicate the structural, microclimatic, nutritive and toxic situations in soils. They are highly suitable bioindicators of soil fertility, and they are known for their sensitivity to synthetic pesticides and to many agricultural practices (Mäder *et al.* 1996, Pfiffner and Mäder 1997). Earthworms help to improve soil structure and provide a high concentration of nutrients in a form accessible to plants (Alföldi *et al.* 2002). Many investigations in Europe and North America show that organically managed soils tend to exhibit a greater abundance and species number of worms compared to conventionally managed plots or farms (review in Pfiffner 1997).

Arthropods

Pesticides can affect beneficial arthropods either directly via contamination, or through alteration of the microhabitat and a reduction of their prey. In contrast to conventional farming, synthetic pesticides are banned in organic farming and the use of a few approved natural pesticides is very restricted. Most natural pesticides are not very selective and can therefore also affect beneficial arthropods. But the toxicity of natural pesticides is usually lower and their degradation significantly faster in comparison to synthetic pesticides (DEPA 1998, UNCTAD 2003). Additionally, the higher fertilisation levels in conventional fields lead to a greater density of crops, which can alter the microclimate and can also reduce the occurrence of species dependent on a warm microclimate and on light (Pfiffner and Niggli 1996, Pfiffner and Luka 1999). Jauset *et al.* (2000) demonstrated that tomato plants fertilised with high nitrogen (N) levels showed a higher intrinsic rate of increase of greenhouse whitefly populations. Yardim and Edwards (2003) studied the effects of organic and synthetic fertilisers on pests (aphids) and predatory arthropods associated with tomatoes. The application of both organic and synthetic fertilisers could increase pest populations. However, they found lower populations of aphids on organically fertilised tomatoes after one year, indicating that organic fertilisers may have the potential to reduce pest attacks in the long term.

In Europe, researchers have found greater diversity and abundance of soil and surface-living arthropods such as spiders, beetles, parasitic flies and wasps as well as non-pest butterflies, and many other invertebrate species in organic farming systems compared to conventional farming systems (Feber *et al.* 1997 1998, Pfiffner and Mäder 1997, Kromp1999, Stolze *et al.* 2000, Sunderland and Samu 2000, Tybrik *et al.* 2004). However, some reports have not found these differences to be as clear (Gardner and Brown 1998), and in the case of aphids, there are generally fewer present in organic fields (Reddersen 1997). Berry *et al.* (1996) examined the abundance and ecological diversity of selected groups of beneficial arthropods on 16 organic and 17 conventional carrot fields in New Zealand. The organic fields had significantly higher numbers of Hymenoptera and Neuroptera as well as a significantly more diverse predatory and parasitic community than the conventional fields.

Birds

The decline in farmland bird populations is well documented. Birds are well-suited indicator organisms that show the environmental status of nature and landscape infrastructure including agricultural land. Several studies show that bird densities are higher in organic farms. A study by Rhône-Poulenc (1997) has shown a steady annual increase in the number of bird territories on land converted to organic production and a larger overall number of territories on organically managed land. The British Trust for Ornithology (1995) found that breeding densities of skylarks and densities of birds in general were significantly higher on organic farms. In coffee production in Latin America, another factor appears more important – research carried out by the Smithsonian Migratory Bird Centre in Colombia and Mexico showed more than 90% fewer bird species in sun-grown coffee plantations as opposed to shade-grown coffee (Alger 1998). Shade-grown practices are recommended in organic standards as they fulfil requirements to enhance soil fertility, pest and disease control and expand crop production options (Rice and Ward 1996). While many interactions between organic farming and biodiversity are positive, some actions can have a negative impact, particularly on ground-nesting birds. These include mechanical weeding, mulching operations, certain mowing techniques and timing of operations (Jones *et al.* 1996, Fuller 1997, Welsh *et al.* 2002, Shepherd *et al.* 2003, Reiter and Krug 2003).

Mammals

According to Hole *et al.* (2005), there are only two strictly comparative studies of organic and conventional farming and their influence on mammalian biodiversity. Brown (1999) found that activity levels of small mammals (wood mouse, bank vole, common shrew) were greater in organic than conventional fields. Increased food abundance through hedgerows and field-edge habitats was cited as the most significant factor that benefitted these and a range of other mammalian species occurring on farmland. Many small mammal species are likely to have been affected by reduced insect and weed-seed food resources resulting from intensification

(Flowerdew 1997). Wickramasinghe *et al.* (2003) investigated bat activity and species richness in a paired (organic/conventional) farm. Total bat activity was significantly greater on organic farms than on conventional farms, while no significant difference in species richness was found between the farm types. Responsible factors for the greater activity levels appeared to be better water quality and greater prey availability.

Comparatively few data are available on the effects of organic farming on other wild animal groups, particularly in regard to pollinators. This could be an important research theme. Apart from wild bees and other insects, bats are the principal pollinators of fruit trees and major staple food crops, including potato, cassava, yams, sweet potato, taro, beans, coffee and coconut. Declines in populations of pollinators now threaten both the yields of major food crops and the survival of wild plant species (McNeely and Scheer 2001). Many vertebrate pollinator species are threatened in Australia, Colombia, Ecuador, Indonesia, Madagascar, Mexico, Papua New Guinea, Peru and the USA. The main reasons include: loss of nesting and roosting sites, habitat fragmentation by excessive exposure of nectar plants to herbicides and pollinators to pesticides, overhunting, disruption of nectar corridors required by migratory pollinators, and competition by invasive species (Nabhan 1998).

Habitat diversity

Semi-natural areas are extremely valuable habitats in the agricultural landscape with respect to the conservation of threatened species. They are also of great functional importance for nutrient cycling (e.g. meadows retaining nutrients and thereby preventing leaching) and processes of succession (e.g. colonisation) (Tybirk *et al.* 2004).

In Denmark, there are four major pressures which affect semi-natural habitats such as permanent grasslands and meadows: changes in hydrology, fragmentation, eutrophication, lack of management and consequently, succession into shrub and forest (Ellemann *et al.* 2001). Tybirk *et al.* (2004) argue that organic farming may affect these biotopes in the same manner as conventional farming except for the absence of chemical fertilisers and pesticides. While pesticides are rarely used on semi-natural areas in general, organic nutrients may be applied by organic farmers at (almost) the same levels as in conventional farming systems. Attention should therefore be given to developing organic farming practices that support the characteristic balance of functional groups of organisms, and that ensure a proper functioning of the relevant processes and functions (Stolton *et al.* 2000). An example is the maintaining of unfertilised buffer strips along uncultivated biotopes (Tybirk *et al.* 2004).

Overall, there is little information available to compare habitat diversity in organic and conventional farming systems. Stockdale *et al.* (2001) and Alföldi *et al.* (2002) indicate that semi-natural habitats are intrinsic in organic regimes where their management is central to the philosophy. Organic farming does indeed tend to have a positive impact on habitat diversity, presumably for the reasons that have already been given. But the correlation is not very strong, since habitat diversity depends highly on given/historic landscape structures and site-specific aspects too (Stolze *et al.* 2000, Shepherd *et al.* 2003, Reiter and Krug 2003).

Diversity and density of habitats in the agricultural landscape may influence the production system, but the overall effects are extremely difficult to determine. There is a great need to intensify research of these interactions and to develop reliable indicators of a supposed functional integrity and both the positive and negative interactions between cultivated and uncultivated areas in organic farming systems (Tybrik *et al.* 2004).

Landscape

Landscapes are territorial or spatial units produced through the interaction between human societies and cultures with the natural environment (Wascher 2000). They are viewed as integrating various functions demanded by society – the multifunctional landscape. In this sense, landscapes can be classified according to their intrinsic beauty, historical features, embodiment of cultural values, past and present impacts of land use, farm practices, composition of farming systems, distribution of habitats and human-made features like stone walls or historic buildings (OECD 1997). Landscape goals and the relevant land use and management practices need to be addressed at the farm as well as at the landscape level. Van Mansvelt and van der Lubbe (1999) as well as van Elsen (2001) suggested that a minimum of 3% to 5% of each farm should be designated to on-farm nature conservation, although the spatial separation of the conservation areas from the production zones should be minimised (van Elsen 2000). Tybirk *et al.* (2004) state that minimum standards on the extent of uncultivated areas should rather be implemented at the landscape level, where due consideration of landform and habitat structure could be taken.

In a comparative analysis of organic and conventional farms in two Danish counties, Tress (1999) found generally fewer fallow fields and a larger area of permanent and extensive grassland on organic farms. More fields of smaller size and a significantly larger share of inner and outer hedgerows on organic farms are creating a more diverse mosaic within the farm (Clausen and Larsen 1997, Tress 1999). Alföldi *et al.* (2002) found that the diversity of landscapes and production systems was greater in organic farms than on conventional farms, regarding land use types, crops, livestock, plantings (hedges, solitary shrubs, trees), flora and sensorial information.

Farms exert a joint but uncoordinated impact on landscape (Baudry *et al.* 2003, Thenail and Baudry 2004). The development of high-input systems has reduced the area of extensively cultivated fields, grassland, uncultivated areas and small biotopes. Therefore, the landscape level management of habitats becomes crucial for the purpose of leaving room for natural processes (Reenberg and Baudry 1999). Development of organic farming in this respect is a potential instrument for such management (Tybirk *et al.* 2004).

Organic farming generally provides a good potential for landscape diversity, including criteria related to perception and sensory qualities (Van Mansvelt and van der Lubbe 1999; Stolze *et al.* 2000; Stobbelaar and van Mansvelt 2000). Van Elsen (1997) states that the basic principles of organic farming provide a perspective for further development of high-quality landscapes which include the possibility of a cautious utilisation of sensitive areas (Noquet *et al.* 1996), as well as a requalifying of the identity of rural sites (Pennanzi 1996). How precisely organic farms (can) contribute to landscape quality is a main area for further research.

Soil

Soil care is a main principle in organic farming. It is, therefore, not surprising that the impacts of organic farming on soil properties have been researched comprehensively. Special focus in this research is on organic matter content, biological activity, nutrient cycles and soil erosion. Even though soil performance is very site specific, results of studies in different countries (e.g. Europe) show that organic farming tends to conserve soil fertility and system stability better than conventional farming systems (Stolze *et al.* 2000, Shepherd *et al.* 2003).

As organic farmers cannot use synthetic substances (e.g. fertilisers, pesticides, pharmaceuticals), they pay particular attention to operating a sound rotational system to 'nourish the soil' in order to maintain organic matter content and to keep it in good condition. Organic management focuses on nutrient cycling with the aim of maximising agroecosystem stability and homeostasis. To restore the natural ecological balance is seen as essential by organic farmers because ecosystem functions are considered to be the main productive 'input' (Alföldi *et al.* 2002, Shepherd *et al.* 2003).

Soil organic matter

The environmental relevance of organic matter content is based on its capacity to improve nutrient availability as well as biological activity and to reduce the vulnerability to physical damage. Soil organic matter strongly influences many soil properties including bulk density, water-holding capacity, infiltration rate, hydraulic conductivity and aggregate stability (Alföldi *et al.* 2000, Shepherd *et al.* 2003). Research on organic matter concentrates on soil organic carbon (C) content as a key parameter. The level of organic matter content correlates with site-specific conditions such as soil type, texture and precipitation as well as farming system (Stolze *et al.* 2000).

Soil organic matter (SOM) and humus are important components in the organic farming philosophy. Fertilisation is based on organic substances such as farmyard manure from animal husbandry, compost, green manure, plant residues and commercial organic nitrogen fertilisers. Consequently, there is an extensive supply of organic matter passing through aerobic decomposition processes. Mineralisation and decomposition processes are influenced by humidity, temperature and oxygen. This means that under tropical conditions these processes run faster and all year long, whereas under temperate conditions they are slower and come to a halt during the colder months (Stolze *et al.* 2000, Alföldi *et al.* 2002).

Several long-term trials that compare organic farming to conventional farming have been performed in various European countries. The research shows that soil organic carbon content is higher in organic systems than in conventional farming (e.g. Goldstein and Young 1987, Garcia *et al.* 1989, Mäder *et al.* 1995, Petersen *et al.* 1997, Clark *et al.* 1998, Stolze *et al.* 2000). As for pastures, the differences are less pronounced (Shepherd *et al.* 2003). However, some authors could not report an increase of SOM in organically managed soils. Gosling and Shepherd (2004) found that soils in England under mixed organic arable rotations maintained concentrations of SOM at similar levels to those under typical conventional systems.

The most important farm practices for organic matter supply vary in different regions as European organic farm characteristics differ considerably between climatic zones. Organic farming in the Northern countries is characterised by a high percentage of leys in crop rotations because animal husbandry is the dominant farm type. SOM content and composition on organic farms in the Mediterranean countries is based more on plant residues and green manure (Persson 1994, Pomares *et al.* 1994, Vizioli 1998, Stolze *et al.* 2000).

Overgrazing and the need for fuel (both wood and dung) in the countries of Africa, Asia, Latin America and the Caribbean can both exert extreme pressures on local bioproductivity, leading to nutrient losses and reducing the amount of available compostable and recyclable organic materials. According to Parrot and Marsden (2002), organic and agroecological systems do not provide panaceas for areas with depleted and declining nutrient status. However, their case studies in Burkina Faso and Tigray (Ethiopia) show that organic and agroecological systems can significantly help address problems of declining soil fertility by building up local productive capacity (both ecological and social), rather than relying upon external inputs.

Acidity and pH levels

The pH of the soil is an important parameter since it can affect the plant's ability to take up nutrients and the microbial activity in the soil that influences the processes required for plant nutrition. Changes in soil pH occur by the displacement of cations or by additions of sources of acidity such as hydrogen and aluminium ions (Tisdale *et al.* 1993).

Chemical fertilisers are highly reactive and can cause extreme pH fluctuations in localised areas such as those near the fertiliser band (Cooke 1967). In contrast, organic manure can increase the buffering capacity of soils, preventing swings in pH, because of additional organic matter. Comparative studies of conventional and organic farming systems revealed that organic systems sometimes have higher pH levels in mildly acidic soils than their conventional counterparts (Alvarez *et al.* 1993, Reganold *et al.* 1993, Drinkwater *et al.* 1995, Werner 1997, Clark *et al.* 1998). During a long-term organic farming study in the Great Plains in Northern Colorado, Daniel *et al.* (2002) found that the pH levels in the alkaline soil decreased significantly over time with organic production. Results from a long-term Swiss trial comparing biodynamic, organic and conventional farming systems, the DOK (bioDynamic–Organic–Konventional) trial, demonstrate that the utilisation of composted manure, common in organic systems, has a positive effect on the content of organic matter and helps to avoid soil acidification (Fließbach *et al.* 2001).

Biological activity

High biological activity within the soil promotes metabolism between soil and plants and is an essential part of sustainable plant production and fertiliser management. The role of soil organisms is central to soil processes and fertility since they render available the elements in plant residues and organic debris entering the soil (Alföldi *et al.* 2002).

Earthworms and mesofauna

Earthworms have many positive direct and indirect effects on soil quality, both in terms of their effects on soil physical properties and nutrient cycling. Furthermore, they are important in soil organic matter turnover (Shepherd *et al.* 2003). As a key species of soil mesofauna, they are an appropriate indicator of soil biological activities as a result of their sensitivity to any kind of soil disturbance (Stolze *et al.* 2000). In a synthesis of relevant scientific results, Pfiffner and Mäder (1997) compared organic and conventional farming systems and concluded that in organically farmed soils, a significantly higher biomass and abundance of earthworms occurred as well as a considerably higher diversity of earthworm species. These results were also reported by Siegrist *et al.* (1998) during a long-term field trial and by others (Gerhardt 1997, Whalen *et al.* 1998). A possible reason for the abundance of earthworms in organic farming could be that organic production depends more on a high, sustained supply of organic substance from plant residues and manure than conventional farming, which can rely at least partly on the mineral supply of nutrients. Organic rotations and particularly the inclusion of grass leys, preferably of several years (>2 years), into farming systems tend to favour earthworms because of the beneficial effects of organic matter additions and leys (Rhône-Poulenc 1997, Neale 1998, Scullion *et al.* 2002). However, organic farming systems rely more on mechanical weed control and in certain crops, on intensive soil tillage as the use of synthetic herbicides is prohibited. This can have negative effects on other key species of soil mesofauna such as Collembola insects (springtails) (Krogh 1994).

Soil microorganisms

The soil microbial biomass serves as a labile source and an immediate sink of carbon, nitrogen, phosphorus (P) and sulfur (S) in soils and performs critical functions such as nutrient transformation and pesticide degradation. Additionally, microorganisms form symbiotic associations with roots, control plant pathogens and participate in soil formation (Shepherd *et al.* 2003). In order to characterise soil microbial activity, parameters like total microbial biomass, diverse enzymatic parameters, carbon turnover and mycorrhization (mycorrhizal soil fungi build up symbioses between fungus and plant) are used. Generally, pesticides affect the population of microorganisms and fungicides tend to inhibit or kill soil fungi, including mycorrhizae (Johnson and Pfleger 1992, Scullion *et al.* 1998) which are particularly important in organic systems. At the same time, however, the evidence for increased microbiological activity under organic farming is mixed. Stolze *et al.* (2000) reviewed European research results and found that an improvement of microbial activity correlated with the period soils were farmed organically. In comparison to conventional plots, several scientists found higher microbial biomass (Mäder *et al.* 1996, Fließbach *et al.* 2001), higher microbial activity and diversity (Beck 1991, Fließbach and Mäder 1997, Fließbach 1998) as well as a higher efficiency in organic carbon turnover in organic plots (Mäder *et al.* 1995). Hole *et al.* (2004) reviewed 14 studies that investigated microbial communities under organic and conventional systems and found only limited differences (Yeates *et al.* 1997, Shannon *et al.* 2002, Girvan *et al.* 2003). However, they detected a general trend towards elevated bacterial (Bossio *et al.* 1998) and fungal (Yeates *et al.* 1997, Shannon *et al.* 2002) abundance/activity under organic systems.

According to Raupp (1995), who reviewed the results of several experiments in Germany, Sweden, Denmark and Finland, the parameters of biological activity were influenced to different degrees by types of organic fertilisers dependent upon type and quality of the applied manure and agronomic techniques (crop rotation, soil tillage). Scow *et al.* (1994) found in the Sustainable Agriculture Farming Systems (SAFS) Project (USA) that after 4 years, microbial biomass levels were consistently higher in organic and low input systems than in conventional systems, while plant parasitic nematode numbers were also consistently lower.

Concerning soil fungi, Elmholt (1996) found a larger number and abundance of saprophytic soil fungi with a higher potential of decomposition of organic material. Furthermore, the degree of mycorrhizal root colonisation was found to be significantly greater in organic plots than in conventional plots (Mäder *et al.* 2002).

Shannon *et al.* (2002) reported recent work under United Kingdom (UK) conditions and concluded that differences in the size, activity and diversity of the soil microbial biomass were subtle, rather than dramatic. They found no consistent differences between organic and conventional farming. A possible explanation for the differing results could be that the level of biological activity changes very slowly in response to altering fertilisation levels and cultivation techniques. This could explain why no differences in microbial activity between organic and conventional plots were observed in several on-farm investigations (Maidl *et al.* 1988, König *et al.* 1989, Necker *et al.* 1992). Several authors state that any experiment trying to assess these changes requires 8–10 years of post-conversion farming (Peeters and van Bol 1993, Rinne *et al.* 1993).

Since 2002, the International Federation of Organic Agriculture Movements (IFOAM) has regulated total copper input on organic farms to a maximum of 8 kg ha^{-1} y^{-1}. These restrictions acknowledge the potential for copper levels in orchard topsoil to accumulate with repeated application. Van Zwieten *et al.* (2004) have demonstrated that copper residues originating from fungicide application reduce soil microbial biomass while stressing the microorganisms. Therefore, it is necessary to better evaluate the potential impacts of copper contamination in agricultural land. In order to reduce the bioavailability of existing residues, management strategies and technologies need to be developed.

On ferralitic soils of the tropics and subtropics, mineralisation occurs much faster than on soils typical of temperate and continental zones. Consequently, a high organic matter content and high biological activity are essential for sustainable soil fertility. The beneficial impacts of organic farming on biological activity, micro-organisms and soil organic matter content are, therefore, particularly important for soils in the tropics and subtropics (Alföldi *et al.* 2002).

Soil structure

The environmental importance of a favourable soil structure lies in an improved resistance to structural soil damage, such as compaction and erosion. Soil structure can be measured by several physical parameters, such as the stability of aggregates, coarse pores, air capacity and water holding capacity. The maintenance of a favourable soil structure is a major concern in organic farming systems. Favourable rooting conditions as a result of microbial activity and a good exchange of water and air ensure improved spatial and chemical availability of nutrients (Stolze *et al.* 2000).

Stockdale *et al.* (2001) reported evidence of increased aggregate stability under organic farming (Jordahl *et al.* 1993, Gerhardt 1997, Siegrist *et al.* 1998). Reganold (1995) showed significant differences in soil structure when 16 fields of biodynamic or conventional commercial farms were compared in a paired study in New Zealand. There were also highly significant differences in total topsoil C and a range of physical parameters (e.g. reduced bulk density and penetration resistance and increased topsoil depth under organic and/or biodynamic farming). Reganold (1988) undertook a similar paired study on a conventional and an organic farm in the USA and again found improved physical properties under the organic system. In contrast, Stolze *et al.* (2000) found that in most relevant long-term trials in Europe no significant differences in soil physical parameters, like macropore volume, bulk density and soil stability, could be detected between organic and conventional farming systems (Meuser 1989, Alföldi *et al.* 1993, Niggli *et al.* 1995). Again, a long time of organic management and longer term changes may be more important than short-term effects.

Erosion

Soil erosion by wind and water is assumed to be the main cause of soil degradation worldwide (Oldeman 1994, Pimentel *et al.* 1995). The loss of fertile topsoil by erosion results in a lower yield capacity, and in an undesired transfer of nutrients, pesticides and sediments in surface water. Although erosion partly depends on site-specific risk factors, such as topography and climate, the extent of damage by soil erosion can be limited by farm management practices. The C-factor (tillage and coverage factor) describes soil losses on a slope relative to soil losses at full fallow (Schwertmann *et al.* 1990) as figured in the Universal Soil Loss Equation (USLE). Organic farming systems are usually characterised by a lower C-factor and a reduced erosion risk because of the wider crop rotations (Stolze *et al.* 2000). In addition, soil management techniques like organic fertilisation, mulching and cover cropping improve soil structure and, therefore, increase the water infiltration and retention capacity, and thus reducing the erosion risk substantially. These management techniques are particularly relevant on the porous ferralitic soils of the tropics and subtropics to reduce the soil erosion risk after heavy rainfall (Alföldi *et al.* 2002).

However, highly effective soil erosion minimising measures like direct drilling and mulch drilling can be found more often on conventional farms than on organic farms as these measures require a herbicide-based management (Dabbert and Piorr 1999, Stolze *et al.* 2000). Comparative data for erosion under organic and conventional systems are rare (Unwin *et al.* 1995). There are only a few studies and the most cited is that of Reganold (1988), who compared the long-term effects (over 40 years) of organic and conventional farming on selected properties of the same soil on farms near Spokane in Washington, USA. The organically farmed soil did not only have a thicker topsoil but also had a significantly higher organic matter content and less soil erosion than the conventionally farmed soil. In the long-term DOK-trial carried out by the Swiss FiBL (Fließbach *et al.* 2001) relevant soil parameters of conventionally and organically farmed soils were compared. One of the results was that organic soil management improved soil structure by increasing soil activity, thus reducing the risk of erosion (Alföldi *et al.* 2002).

In conventional farming in the tropics, even flat soil gets eroded as a result of the use of herbicides and the lack of soil cover; however, organic farming can counter erosion successfully. In trials on a Cuban citrus plantation, the Cuban Citrus Institute and Swiss FiBL used locally adapted leguminous crops and were able to restore degraded soils very quickly, to successfully suppress weeds, to fix nitrogen and prevent erosion (Alföldi *et al.* 2002). Parrott and Marsden (2002) report that the shift to biodynamic methods in the Ambootia Tea Estate (Darjeeling, India) has significantly reduced problems of soil erosion and risk of landslide, and increased retention of soil moisture in an area with very seasonal rainfall.

Desertification

Since organic farming techniques have the potential to improve soil fertility, soil structure and moisture retention capacity, organic management provides solutions to the problems associated with desertification (degradation of drylands). Relevant techniques in this context include composting, mulching, use of cover crops, intercropping, the use of supplemental organic fertilisers and mineral fertilisers (e.g. rock powder, rock phosphate, potassium sulfate). Additional benefits are provided by the frequent use of endemic species which are more adapted to climate stress, as well as the use of water preserving and agroforestry techniques (Djigma *et al.* 1990, Harris *et al.* 1998). With a high level of organic matter and permanent soil cover, the water and nutrient retention capacity is increased and microorganisms create a stable soil structure. Organically managed soils, therefore, tend to be more resilient to water stress and to nutrient loss. The high moisture retention capacity can substantially reduce the amount of water needed for irrigation (Alföldi *et al.* 2002).

The organic farming's potential for countering desertification is demonstrated by some practical examples in arid areas. In Kenya, the International Centre for Research in Agroforestry (ICRAF) runs organic farming projects to fight drought (Stolton 1997). Agroforestry systems generate multiple benefits, including erosion control and moisture retention (Alföldi *et al.* 2002). The organic farm Fazenda Tamanduà in Brazil is situated in an arid area severely affected by salinisation resulting from inappropriate irrigation techniques. It is a certified organic farm with more than 3000 ha of which 650 ha are cropped with mango trees. Conventional agriculture in the area uses the water from the rivers and causes further salinisation by overirrigation. By using only rainwater, the Fazenda Tamanduà avoids the depletion of water resources and reduces soil salinisation considerably. Fertilisation regimes include grazing cattle under mango trees as well as application of composted manure (Alföldi *et al.* 2002).

According to Harris *et al.* (1998) organic farming offers a favourable option in arid areas, but has to face constraints such as a lack of knowledge, lack of organic materials, land-holding constraints and the perception of organic farming as being old fashioned. The examples above have shown the potential benefits of organic farming for countries hit by desertification. Organic management could be a key to bringing degraded land back into production and therefore significantly contribute to the solutions of the world food problem. Governments would need, however, to actively promote organic farming systems and land reform (Alföldi *et al.* 2002).

Ground and surface water

The harmful effects of intensive agriculture on ground and surface water are caused mainly by the following practices (Stolze *et al.* 2000, Alföldi *et al.* 2002):

- excessive application of mineral N fertilisers, nutrient surpluses and a high level of available nitrogen after harvest;
- high organic fertilisation level in combination with high stocking rates;
- contamination of water with synthetic pesticides; and
- lack of a protective soil cover, a narrow crop rotation and frequent tillage.

In areas where water is scarce (e.g. in the Mediterranean countries and in arid and semiarid zones), excessive water use, particularly for irrigation, is a problem. National standards for organic farming in Europe set up limits for irrigation in order to conserve water resources (David *et al*. 1996).

Nutrient use and balance

The general conclusion that can be drawn from the literature is that organic farms often have smaller nutrient surpluses than conventional farms. Obviously, the same farm types need to be compared because livestock farms often have higher nutrient surpluses. It follows that in organic farming, the risk of water and air contamination as a consequence of nutrient surpluses tends to be lower (Stolze *et al*. 2000, Shepherd *et al*. 2003).

Restrictions in organic standards include a ban of mineral N fertilisers and a limitation of livestock density. More characteristic of organic farms, therefore, is that N tends to be a minimal factor, particularly on arable farms. Since the opportunity costs to produce N on-farm in organic systems can amount to from seven to 16 times the cost of mineral N fertilisers (e.g. Stolze 1998), it is of particular economic interest to avoid N losses. As far as nutrient deficiencies are concerned, Unwin *et al*. (1995) argue that the medium-term effects of an unbalanced nutrient supply are likely to take the form of a reduction in economic performance rather than environmental detriment.

Nitrate leaching

As a result of fertiliser or manure applications as well as N fixation by leguminous crops, N accumulates in the soil. Nitrate leaching occurs when the amount of nitrate in the soil exceeds the plant's requirements and when water from rain, irrigation or snowmelt moves through the soil into the groundwater. Nitrate in water can lead to toxic contamination of drinking water for humans and animals, as well as an eutrophication with excessive algal growth. The most common parameters used are the nitrate leaching rate and the potential for nitrate leaching (Stolze *et al*. 2000).

Variation in leaching from individual fields is large both in organic and conventional agriculture. Many organic systems operate at a lower level of N intensity than conventional systems because of lower stocking rates and fertilisation levels. Another reason for lower N losses in organic farming is that their application is bound to organic manure and its corporation into the soil. Straw-based manure, common in organic farming, reduces the nutrient availability and the risk from run off in comparison to slurry. Other organic farming practices which minimise losses are wide crop rotations, soil cover during winter, intercrops, underseeds and fallows of several years (Nocquet *et al*. 1996, Dabbert and Piorr 1999, Shepherd *et al*. 2003).

Nitrate leaching in meadows, where herbage is removed from the field, are generally small. Greater losses occur where pastures are grazed because of the large returns of N in excreta. The flush of N mineralisation following the ploughing up of leys is another feature of organic systems that possibly increases the risk of nitrate leaching (Stopes and Philipps 1992, Scheller and Vogtmann 1995). Leaching from arable land is increased where fertiliser rates exceed crop requirements. In particular, losses are associated with the temporary nature of annual crops and, sometimes, the lack of synchrony between release of N from organic matter and crop uptake. Improving the fertility of organically farmed soils by building up the content of SOM and incorporating organic residues and manures may increase this risk (Shepherd *et al*. 2003).

Taking all these factors into account, overall leaching losses from organic farms tend to be less than from conventional farms (Edwards *et al*. 1990, Younie and Watson 1992, Eltun 1995). Using a modelling approach, Condron *et al*. (2000) found that conventional dairy farms in

New Zealand had higher annual losses than organic dairy farms. Farm comparisons in Europe presented by Stolze *et al.* (2000) show that nitrate leaching rates in organic farming in most studies are significantly lower than those of conventional systems. However, if the nitrate leaching rate is related to the output of grain and milk, organic systems tend to perform similarly or even worse.

The farm level data are supported by the results of nitrate screening. Large-scale surveys in water protection areas in Germany and Denmark indicate that organic farming results in a lower or at least similar potential for nitrate leaching into ground and surface water. The absolute values generally did not exceed critical levels. As a result of improved conventional (integrated) management of mineral N fertilisation, or systems using extensification measures especially in water reclamation areas with strict regulatory standards and extensive control measures, differences between organic and conventional systems have become smaller recently (Piorr and Werner 1998).

Even though scientific results from other climatic zones are scarce, positive effects of organic farming on the nitrate leaching risk can be reported from a citrus farm in Cuba. Under organic fertilisation management based on composting with 60 kg N ha^{-1}, the farm achieved exactly the same yield level as under conventional fertilisation management with 200 kg of mineral N. This example shows that organic fertilisation management can help reduce the risk of nitrate leaching, especially under extreme climatic conditions (Kilcher 2001).

Although not all the results showed that organic farming results in less nitrate leaching than conventional farming, a strong tendency towards a decreased risk of nitrate leaching can be deduced. Losses after ploughing of leys for instance, can be large. But the growing consciousness of problematic phases in crop growth or cultivation has resulted in improvements in organic management practices. The remaining differences may decline as conventional fertiliser practices improve under increasing regulatory pressure (Stolze *et al.* 2000, Shepherd *et al.* 2003).

Phosphorus

The main pathway for P losses is by movement of soil particles (i.e. together with soil erosion). Leaching is a much smaller and a more site-limited effect. Although the quantities of P lost from farmland are usually small in agricultural terms, losses of a few kilograms of P per hectare are sufficient to be of environmental concern (Shepherd *et al.* 2003). Leaching is most likely on deep sandy soils or high organic matter soils with little capacity to adsorb P (Sims *et al.* 1998, Haygarth and Jarvis 1999).

Data on P leaching and runoff from organic agriculture are scarce. As nutrient balances for organic farms rarely show a significant surplus of P, losses are assumed to be small (Edwards and Withers 1998). A more reliable indicator to determine losses could be the differences in the dominant loss pathways in livestock and arable farming.

Because of the relatively infrequent use of P and potassium (K) fertilisers in organic farming (e.g. rock phosphate, sugar beet processing waste), organic systems have been criticised for exploiting reserves of P and K built up by conventional farming (Nguyen *et al.* 1995, Greenland 2000, Oehl *et al.* 2002). Some authors have reported a decline in the concentration of extractable P and K in soils after conversion to organic management (Haraldsen *et al.* 2000, Løes and Øgaard 2000), but this decline does not always occur, even where budget deficits of P and K are measured (Watson *et al.* 2000). Gosling and Shepherd (2005) have researched long-term (over 15 years) changes in soil fertility in organic farming systems in England. Their results support the argument that organic arable systems are mining reserves of P and K. Therefore, they state that changes to organic management practices are required in order to increase inputs of P and K, if long-term declines in soil fertility are to be avoided. In the case of broadacre organic farming in Australia, soil available P has declined to levels where yields are being compromised and the sustainability of the farming system is being questioned (Penfold 2000).

Pesticides

The term 'pesticide' covers a wide range of chemicals (e.g. fungicides, herbicides, insecticides, acaricides, algicides, lumbricides, molluscicides, nematicides, rodenticides, plant growth regulators). Pesticide use in organic farming is very restricted. Only a few pesticides are approved for organic use (e.g. sulfur, copper, natural pyrethroids) and tend to be used only as a last resort for minority or protected crops. Synthetic pesticides are completely banned (Shepherd *et al.* 2003). In addition to the pollution of surface and groundwater, there is also a risk of air and soil contamination.

Many reviews come to the same conclusion: because synthetic pesticides are not permitted for use in organic agriculture, the risk of contaminations of air, soil and water in this respect is avoided (Condron *et al.* 2000, Stolze *et al.* 2000, Hansen *et al.* 2001, Stockdale *et al.* 2001). According to Unwin *et al.* (1995), the spraying of pesticides permitted in organic farming is connected with a comparatively negligible risk due to low volatility. The exposure of certified biocides is measured at extremely low levels when compared to conventional systems in organic permanent crops, these being more prone to pests and diseases (Kabourakis 1996). The application of powdered and fluid substances permitted by organic standards may cause a short-time impairment of air quality (Stolze *et al.* 2000).

The impact of pesticides on water quality in organic systems has rarely been studied (Stockdale *et al.* 2001). Again, however, most of the water contamination comes from herbicides used in conventional farming. There is some debate about the disposal of sheep dip and the relative risks of pyrethroids versus organophosphates. Organic farmers only use the former and they are potentially more damaging to aquatic habitats.

Pathogens

Pathogenic organisms from livestock can contaminate surface waters used for drinking, bathing or irrigation. The application of organic manures to agricultural land is one route by which pathogens may be introduced into the human food chain. There are only few data available on the relative risks of pathogen transfer from organic and conventional farming systems.

Pathogen levels can decline during manure storage, particularly if solid manure is actively composted to increase the temperature of the heap (Kudva *et al.* 1998, Himathongkham *et al.* 1999, Nicholson *et al.* 2002). Thus, it might be concluded that biodynamic farming provides a lesser risk because manures are more often composted. So far, there are no data to prove this, but research is on-going (Shepherd *et al.* 2003).

The overuse of antibiotics and pesticides in conventional farming, in horticulture and especially intensive enterprises like poultry farming, has the potential to lead to drug resistance of pathogens and consequently to the contamination of the environment and the food supply (APHA 2002, Allersberger *et al.* 2003). In organic farming, the use of regular synthetic veterinary medicines is restricted and the use of antibiotics for preventive treatments prohibited (Kijlstra *et al.* 2003). Therefore, organic agriculture does not carry the same risk as conventional agriculture.

Climate and air

Global climate change (greenhouse effect) is considered one of the most urgent environmental problems. The gases carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) mainly contribute to the greenhouse effect and are largely, directly or indirectly, as a result of the burning of non-renewable resources. On a global scale, agriculture is responsible for roughly 15% of the trace gas emissions with climatic impact (Burdick 1994, Cole *et al.* 1997, Stolze *et al.* 2000). However, agriculture also provides a sink for CO_2 because of the fixation of carbon by crops and pasture.

An important side-effect of global warming could be that cultivation zones will shift polewards and that agricultural yields will be affected. Reilly *et al.* (1996) and others expect that extreme climatic events will occur more frequently and that this will jeopardise plant production.

Carbon dioxide

Carbon dioxide emissions from the agricultural sector in OECD countries are estimated at less than 1% of overall CO_2 emissions (IPCC 2001). Net emissions of CO_2 from agriculture depend upon the direct and indirect use of fossil fuels, and on the amount of carbon sequestration in soil organic matter and crop growth (Shepherd *et al.* 2003).

In order to compare farming systems CO_2 emissions need to be differentiated between the emission due to the burning of fuel (direct energy) and the fuel used for the production and transport of fertilisers, machinery and synthetic pesticides (indirect energy). Haas *et al.* (1995) found that 70% of CO_2 in organic farming resulted from fuel consumption and the production of machinery, whereas 75% of the CO_2 emissions in conventional systems were due to N fertilisers, feedstuff and fuels.

On a per hectare scale, most studies found lower (up to 40–60%) CO_2 emissions in organic systems (Burdick 1994, Haas and Köpke 1994, Stolze *et al.* 2000). The main reasons for these positive effects are the renouncement of the use of mineral N fertilisers with high energy consumption, lower use of high energy consuming feedstuffs and mineral fertilisers as well as the elimination of pesticides. But, on a per unit output scale, which mainly depends on the yield that is achieved, CO_2 emissions tend to be higher in organic farming.

Carbon sequestration

According to Tilman (1998), soil carbon levels have decreased under agricultural land use. Therefore, sustainable agricultural strategies including recycling of organic matter, tightening nutrient cycles, and low-tillage or no-tillage practices may rebuild organic matter and reduce losses from the system. Haas and Köpke (1994) calculated that, despite generally lower crop yields, plant productivity in organic farming accounts for almost the same organic matter return as in conventional systems. Drinkwater *et al.* (1998) found over a 15 year period that mixed farming with manure application and the combination with other organic farming techniques lead to significantly higher organic matter levels in soil as compared to conventional farming.

There is a huge potential for CO_2 sequestration, which differs for tropical and temperate countries. Developing countries, mostly in the tropical belt, have a 30–60% higher potential than industrial countries, mainly located in temperate climatic regions. Agroforestry holds the highest potential of agricultural carbon sequestration in tropical countries and is seen as a viable alternative to slash-and-burn agriculture in the humid tropics (Kotschi and Müller-Sämann 2004). Simple agroforestry systems with one species (e.g. oil palm, rubber) can regain 35% of the original carbon stock of the forest, which is three times more than cropland and pastures (Palm *et al.* 2000). Extensive research on the situation and on the potential impact of agroforestry has been undertaken by ICRAF for East and Southern Africa. Carbon stocks can be tripled over 25 years, similar results can be assumed for subhumid West Africa and subhumid South America, but there is little researched evidence (FAO 2001). Sound technologies have been developed to sequester additional carbon in cropland management and in agroforestry and they are systematically applied and improved in organic farming. The evidence of their performance is still fragmentary, however, and does not allow regular comparison and quantification for the various agroclimatic regimes and socioeconomic patterns (Kotschi and Müller-Sämann 2004).

Burdick (1994) concluded that organic farming enables ecosystems to better adjust to the effects of climate change and it also offers a major potential to reduce the emissions of agricultural greenhouse gases. Moreover, mixed farming and the diversity of organic crop rotations are protecting the fragile soil surface and may even counteract climate change by restoring the organic matter content (Haas and Köpke 1994). The carbon sink idea of the Kyoto protocol may therefore be accomplished efficiently by farming organically (Alföldi *et al.* 2002).

Nitrous oxide

Nitrous oxide contributes severely to global warming and the depletion of ozone in the stratosphere (Crutzen 1981, Bouwman 1996). Almost 90% of the global atmospheric N_2O is formed during the microbial transformation of nitrate (NO_3^-) and ammonia (NH_4^+) in soils and water. In OECD countries the agricultural contribution to N_2O emissions is estimated at 58% (IPCC 2001). Soils fertilised with inorganic fertilisers and manure stores are seen as the largest sources (Chadwick *et al.* 1999, Brown *et al.* 2002).

Nitrous oxide emissions are very difficult to measure and, therefore, have been related to the total N input in the form of fertilisers, manures and crop residues (Flessa *et al.* 2002). Consequently, it has been largely assumed that, because organic farming operate at a much lower intensity, with lower N inputs and less available mineral N in both manures (Shepherd *et al.* 1999) and soils, N_2O losses will also be lower (Köpke and Haas 1994, Stolze *et al.* 2000, Alföldi *et al.* 2002). However, until recently there have been no quantitative comparisons between organic and conventional systems. Within conventional agriculture, the main risks arise from manures and from the waterlogging of soils by heavy rainfall following fertiliser application. Within organic farming, the main risks come from manures and the incorporation of residues from legumes. In the absence of direct measurement, one may assume that the amount of N_2O lost per unit of yield is unlikely to differ to that from conventional systems, but losses per unit area may differ, depending on the cropping system and input of organic manures (Stolze *et al.* 2000, Shepherd *et al.* 2003).

Methane

Schönwiese (1995) calculates the CH_4 share in the greenhouse effect of about 2.5% and agriculture is believed to account for roughly two-thirds of the total human-generated CH_4 (Watson *et al.* 1996). While paddy rice fields, cattle feedlots and the burning of biomass contribute to methane emissions, about 75% of methane on farms is emitted directly from ruminant animals, from digestive processes and excretion (Stolze *et al.* 2000, Alföldi *et al.* 2002, Shepherd *et al.* 2003).

In order to assess the overall methane emissions from farming systems, several factors like animal numbers and type, diet and manure management system need to be considered as well as their interactions. Diets, that are high in roughage, for example, will release higher rates of methane than diets high in starch. This may result in higher emissions from organic systems, where diets tend to be high in roughage and low in concentrates (Shepherd *et al.* 2003). The higher proportion and lower productivity of ruminants in organic farming may lead to slightly higher CH_4 emissions. But according to Alföldi *et al.* (2002), standards and breeding programs in organic systems aim at longevity in order to prolong the productive period in relation to the 'unproductive' life of young cattle. Correspondingly, the 'unproductive' CH_4 emission of calves and heifers may be reduced (Sundrum and Geier 1996).

Comparative empirical studies on CH_4 emissions in different farming systems are scarce. Flessa *et al.* (2002) compared a conventional and an organic farm rearing beef cattle in southern Germany and calculated that CH_4 emissions were about 25% higher on the conventional farm.

On the basis of the literature reviewed and expert knowledge, only the following conclusions (based mainly on studies for milk production) can be drawn: as a result of lower stocking densities, organic farming might have a lower CH_4 emission potential on a per hectare scale, whereas per unit output, the CH_4 emission potential tends to be higher than in conventional farming (Stolze *et al.* 2000, Shepherd *et al.* 2003). However, in the absence of extensive solid data, no significant differences between the two farming systems with respect to CH_4 emissions can be identified.

Ammonia

Ammonia does not contribute to the greenhouse effect, but causes acidification and eutrophication when redeposited to soils and water and can damage sensitive habitats (Roelofs and Houdijk 1991). In agriculture, livestock production, in particular, accounts for the main part of NH_3 emissions. Ammonia is produced when urea in urine and dung comes into contact with the enzyme urease, which can be found in both manure and soil. Therefore, animal housing, manure stores and the spreading of manures to land are major sources of NH_3 (Shepherd *et al.* 2003). There has been a large amount of research into NH_3 emissions from conventional animal production but only a few studies specifically on organic farms (Stockdale *et al.* 2001).

Differences in dietary N intake and N excretion, housing system and period, manure storage and spreading, and livestock density will affect the amount volatilised (Stolze *et al.* 2000). Since organic systems operate at a lower level of intensity, NH_3 losses may be lower too.

Emissions from housed animals are considered to be greater than those from grazed, as urine is quickly absorbed into soils. In organic systems, maximum grazing is recommended, which tends to reduce housing periods. Therefore, the potential for ammonia loss is likely to be less, although this has not been tested (Stolze *et al.* 2000). Straw-based systems also tend to have lower emission rates than systems based on slurry; the latter are more common in conventional farming (Pain *et al.* 1998). Furthermore, much evidence suggests that ammonia losses are greater from composted manures compared to those which are just stockpiled (Shepherd *et al.* 1999, Gibbs *et al.* 2000).

Studies in Europe reviewed by Stolze *et al.* (2000) suggest that organic farming tends to bear a lower potential for NH_3 emissions than conventional farming systems. In a scenario of complete conversion to organic farming, Köpke (2002) estimated a potential reduction of acidification by more than 30%, caused mainly by reduced ammonia emissions. In contrast, Unwin *et al.* (1995) provides a risk assessment upon which NH_3 emissions will not necessarily be lower in organic farming than in conventional. In the absence of direct measurements, one may assume that the amount of NH_3 lost per unit of yield is unlikely to differ to that from conventional systems, but that losses per unit area are likely to be less, due to lower livestock densities (Shepherd *et al.* 2003).

Energy

The OECD (1997) proposed to use energy intensity and efficiency as appropriate indicators to measure and evaluate energy use. The corresponding parameters are:

- energy consumption (per hectare and per output); and
- energy efficiency (input/output ratio).

Several studies have been conducted on energy use in organic farming systems that differ in methodology and in the boundaries of the systems being studied. Furthermore, there is no clearly defined system of conventional farming, which ranges from high input intensive systems to near-organic systems. Therefore, it is difficult to make meaningful comparisons. This must be taken into account when drawing conclusions from studies that compare organic and conventional systems (Refsgaard *et al.* 1998).

Intensity of energy use

Direct on-farm consumption of fossil energy (e.g. for fuel and oil) needs to be distinguished from indirect energy consumption, which results from the production of synthetic fertilisers and pesticides, the transport of imported feedstuffs and from investment goods such as agricultural machinery (Stolze *et al.* 2000).

Inputs of direct energy per unit area in the long-term DOK trial in Switzerland were similar across conventional, low input and organic systems (Alföldi *et al.* 1995). Since basic operations such as ploughing, cultivation, sowing and harvesting are likely to be similar, reduced fuel costs in organic systems due to the absence of most pesticide applications and lower harvesting energy inputs because of lower yields, are more or less balanced by increased fuel use for mechanical weed control.

Inputs of indirect energy tend to be substantially lower in organic systems. The major difference is the greater energy use in conventional systems to produce and transport fertiliser, particularly N fertilisers (Alföldi *et al.* 1995, Cormack 2000, Stolze *et al.* 2000).

If both direct and indirect energy use are considered together, calculations of energy consumption per hectare indicate that organic farms use less energy than conventional farms (Haas and Köpke 1994, Kalk *et al.* 1996). Lampkin (1997) calculated that average energy consumption on organic farms amounts to 64% of conventional farms. Zarea *et al.* (2000) in Iran and Fließbach *et al.* (2001) in Switzerland determined that the energy consumption of organic farms amount to 30% to 50% of conventional farms. For organic potatoes and apples, energy consumption per output unit is higher relative to conventional production. This is the result of a higher energy input for mechanical measures like weed control and the lower mineral N fertiliser use in conventional production (Alföldi *et al.* 2002).

Barbera and La Mantia (1995) found lower energy consumption on organic farms for olive and citrus production in Sicily (Italy), both with regard to energy consumption per hectare and per output unit. A comparison of the energy use per hectare for organic and conventional farming (e.g. in UK, USA, the Philippines) showed a 30% to 70% lower consumption per unit of land for organic systems (Pretty and Ball 2001).

Efficiency of energy use

There are varying results on the energy efficiency of different farming systems. In many organic systems, the yield of crop and animal products is less than in conventional systems (Alföldi and Niggli 1994, Stockdale *et al.* 2001). However, the size of the differences will depend on factors such as farm type, soil type, climate and the intensity of production (Shepherd *et al.* 2003). Furthermore, no standardised scheme for calculating energy use efficiency exists. Shepherd *et al.* (2003) state that analysis should take account of overall farm energy balance and also include activities that are not crop specific (e.g. handling and application of manures and fertilisers, winter catch crops, use of fallows for weed control). However, apart from a few studies based on long-term rotation experiments (Alföldi *et al.* 1995, Hülsbergen and Kalk 2001) these energy inputs have not been considered. Thus, comparing individual research results in this context is only of limited value (Stolze *et al.* 2000).

Nguyen and Haynes (1995) found little difference in overall energy efficiency when they compared mixed sheep and arable farms in New Zealand. But they noted that the conventional farms relied more on legumes for N supply, and therefore were more energy efficient than European equivalents. Smolik *et al.* (1995) compared conventional, minimum tillage and alternative (equivalent to organic) systems of growing soya, wheat and barley over seven years in South Dakota, USA. Overall, the alternative system had the greatest energy efficiency. The minimum tillage system had the lowest efficiency because reduced direct energy input, as tractor fuel, was more than balanced by increased fertiliser and herbicide energy input.

Comparing rotations of different productions systems in Iran, Zarea *et al.* (2000) found the energy efficiency of organic farming to be 81% better compared to high-input conventional farming. In a similar investigation in Poland, Kus and Stalenga (2000) calculated a 35% higher energy efficiency of organic compared to conventional farming.

Overall, the literature review suggests that organic methods generally use less energy per unit area and per unit of output, both for individual crops and livestock types, as well as on a whole-farm basis. Again, however, the setting of system boundaries, methods of calculating the energy values of inputs and methods of calculating energy use efficiencies vary substantially between studies. Comparisons across studies are hardly possible – there is an urgent need for a commonly agreed standard methodology (Shepherd *et al.* 2003).

Conclusions

Is organic farming more environmentally friendly?

The evidence presented in this chapter indicates that there is wide agreement that organic farming comes closest to an environmentally friendly agriculture (Table 12.2). Particularly pronounced is the significant level of pesticide pollution in conventional agriculture; in organic farming, in contrast, there is only a very limited use of pesticides. The differences are likely to hold whether assessed per area or per unit of food produced (Shepherd *et al.* 2003). A second major area where organic farming is more environmentally friendly is soil conservation. Soil care is a guiding principle in organic agriculture. It is expressed in higher levels of soil organic matter, the active promotion of soil biological activity, more balanced nutrient cycles and lower soil erosion risks. A third main benefit is the expressed goal to enhance biodiversity: organic farming depends upon intact ecological balances and favourable biological processes expressed in ecological services like pollination or pest control by natural predators (Alföldi *et al.* 2002). Stolze *et al.* (2000) and others conclude that organic farming creates more favourable conditions at the species and ecosystems level of floral and faunal diversity than conventional farming systems.

Less affirmative, though not necessarily less favourable than for conventional systems, is the evidence that has been presented in fields like pollution of water resources and the food chain with pathogens (due to the more pronounced use of organic fertilisers and manure). The same applies to the emission of N_2O and CH_4 (because manure stores are seen as a major source and because, on an output unit scale, the CH_4 emission potential tends to be higher in organic farming).

Organic agriculture is not exempt from the trend of intensification. Therefore, Reiter and Krug (2003) and others stress that the increasing economical pressures endanger the positive aspects of organic farming. In order to maintain the view of nature conservation of valuable grassland, for example, a very low intensity of production is necessary. But because of increasing intensification, this is hard to realise (Hopkins and Hrabe 2001). The same economic

Table 12.2 Overview of the absolute and relative environmental impacts of organic farming compared with conventional farming (author's compilation based on the empirical material presented in this chapter)
'Absolute' refers to the impact of organic farming on the environment and 'relative' refers to the relative impact in comparison with conventional systems.

Area	Aspect	Environmental impact[A]	
		Absolute	Relative
Biodiversity	Genetic diversity	+	+
	Floral diversity	+	++
	Faunal diversity	+	+++
	Habitat diversity	+?	+
Landscape	Landscape structures and aesthetic value	+?	+
Soil	Soil organic matter and acidity	?	++
	Biological activity	+?	+++
	Soil structure	?	+
	Erosion	–	++/–
	Desertification	+	+
Ground and surface water	Nutrient use and balance	–	++
	Nitrate leaching	–	++/–
	Phosphorus	0	+?
	Pesticides	–	+++
	Pathogens	–	–?
Climate and air	Carbon dioxide (CO_2)	+?	+?
	Nitrous oxide (N_2O)	–	+/-?
	Methane (CH_4)	–	?
	Ammonia (NH_3)	–	+/–?
Energy	Intensity of energy use	na	++/–
	Efficiency of energy use	na	+?

[A] + = Slightly better; ++ = better; ++ = substantially better; ++/– = better with some aspects that are negative; +? = better with some uncertainties; +/–? = partly better and partly worse with some uncertainties; ? = unclear; – = negative impact; 0 = no impact or change; na = not applicable.

pressures lead to a rationalisation of organic production that, in many respects, starts to resemble the rationalisation path of conventional agriculture (Knickel 2001). Field parcel sizes are being continuously increased, agricultural workers are being replaced by larger machinery, and livestock husbandry systems are becoming more rationalised and often more intensive. Clearly, organic farming has the potential to develop sustainable land use systems, but the motivation of farmers and financial support are the main factors required to achieve this goal (Van Mansveldt *et al.* 1998). Organic management could also be a key to bringing degraded land back into production and therefore significantly contribute to the solutions of the world food problem (Alföldi *et al.* 2002).

Organic farming in protected areas

Protected areas are dedicated to the protection and maintenance of biological diversity (as defined by the World Commission on Protected Areas). Since organic farming can support biodiversity, it offers an important agricultural management option (Stolton and Dudley 2000b). In Italy (e.g. in Tuscany) or Germany (e.g. in biosphere reserves such as Schorfheide-

Chorin), organic farming is specifically promoted in protected high nature value areas (Knickel 2001, Stolton and Geier 2002, Kullmann 2003).

Not only in developed countries but also in the developing world the nature conservation agenda is one of the driving forces behind the growth of organic farming. A recent literature survey highlights examples where nature conservation organisations are working closely with local farmers who live in, or close to, areas of significant nature conservation interest (Parrot and Marsden 2002). The Estancia Itabo in Paraguay is an example. It is a protected area of 5000 ha of high quality Interior Atlantic Forest where organic cultivation of yerba maté (*Ilex paraguariensis*) and the heart of the palm *Euterpe edulis* is in line with conservation goals (Pryor 2000). Another example is the buffer zone of the Ampay Forest Sanctuary in Peru, where organic farming practices are promoted (Flores-Escuerdo 2000). In the Meso-American Biological Corridor, a projected complex of protected areas and sustainable management stretching over seven countries, a range of sustainable land uses within buffer zones and linking areas have been explored, including certified forest management and organic agriculture (Stolton and Dudley 2000a; Miller *et al*. 2001).

Future research needed

The main gaps in the literature (and presumably research) on the environmental effects of organic farming can be summarised as follows.

- Scientific evidence of the environmental impacts of organic farming for the Southern hemisphere is rare. More research on the environmental services and benefits or impacts of organic farming is urgently needed.
- The knowledge of the impacts of organic farming in pastoral and upland agriculture is limited. Therefore, a need for longitudinal, system-level studies that address these issues remains. Furthermore, well-replicated studies are required that follow the development of flora and fauna on organic farms during and after conversion, and compare them with neighbouring farms that continue with conventional management.
- The complexity of interactions between species and ecosystem functions are not yet fully explored so that simple biological indicators of soil productivity are yet to be identified. In particular, more research is needed on the interactions between the diversity and density of habitats in the agricultural landscape, and the performance of production systems. Both the positive and negative interactions between cultivated and uncultivated areas in organic farming systems need to be covered. Reliable indicators of a supposed functional integrity need to be developed.
- Comparatively few data are available on the effects of organic farming on wild animal groups (e.g. birds, mammals, amphibians, arthropods). There is particular urgency with regard to the questions of pollinators. Organic farming (like conventional farming) is not able to support highly specialised species which depend on complex mosaics of habitats. Strategies to optimise nature conservation within organic systems are therefore required (Reiter and Krug 2003). Particular attention should be given to developing organic farming practices that support the healthy functioning of the relevant ecosystem processes and functions.
- The basic principles of organic farming provide opportunities for the further development of high-quality landscapes and a cautious utilisation of sensitive areas (Noquet *et al.* 1996). How precisely organic farms (can) contribute to landscape quality should become a main area of further research. There is, for example, little information available to compare habitat diversity in organic and conventional farming systems. Particular attention should be given to developing reliable indicators of both the positive and

negative interactions between cultivated and uncultivated areas in organic farming systems.

- Only very scarce research is available on the interrelationships with climate (change) and air pollution. Studies are needed which analyse CO_2 emissions and accumulations of different farming systems in a net balance approach.
- The development of methodologies for evaluating landscape quality has just begun and quantitative research investigating the impacts of different farming systems on landscapes is scarce. Clearly, the development of methodologies that deal with landscape quality in an integral way deserves greater attention in order to assist the evaluation of environmental impacts (Hansen *et al.* 2001). Particularly little is known about the influence of organic agriculture to aesthetical attributes of the farming landscape. At the same time, the assessment of landscape in terms of an area's visual character is likely to become increasingly important as public money is used to support delivery of 'social goods'. How an organic farm can contribute to the landscape should be a main area of interest for further indicator development (Shepherd *et al.* 2003).
- There is an urgent need for a commonly agreed standard methodology for calculating energy use efficiency. Critical questions include the setting of system boundaries, the methods used for calculating the energy values of inputs and the methods used for calculating energy use efficiencies (Shepherd *et al.* 2003).
- As for the development of agrienvironmental indicators, there has been substantial progress since 1990. Particularly useful are the schemes developed by OECD, Eurostat and the European Environmental Agency (EEA). The main challenge is to apply these schemes in practice, because in many areas and in most parts of the world, an environmental monitoring that is sufficiently disaggregated in temporal and spatial terms is still rudimentary.

References

Alföldi, T. and Niggli, U. 1994. Input and output of energy for different crops in bio-dynamic, bio-organic and conventional production systems in a long-term field trial in Switzerland. In: Borin, M. and Sattin, M. (eds) *Proceedings of the Third Congress of the European Society for Agronomy*, Padova University, Padova. pp. 650–651.

Alföldi, T., Stauffer, W., Mäder, P., Niggli, U. and Besson, J.-M. 1993. DOK-Versuch: vergleichende Langzeituntersuchungen in den drei Anbausystemen Biologisch-dynamisch, Organisch-biologisch und Konventionell. III: Boden: Physikalische Untersuchungen, 1. und 2. Fruchtfolgeperiode. *Schweizerische Landwirtschaftliche Forschung* 32(4): 465–477.

Alföldi, T., Spiess, E., Niggli, U. and Besson, J.M. 1995. Energy input and output for winter wheat in biodynamic, bio-organic and conventional production systems. In: *Soil Management in Sustainable Agriculture. Proceedings of the First Meeting of the Concerted Action AIR3-CT94-1940, Fertilisation Systems in Organic Farming.* Institute of Biodynamic Research, Darmstadt. pp. 3–15

Alföldi, .T, Fließbach, A., Geier, U., Kilcher, L., Niggli, U., Pfiffner, L., Stolze, M. and Willer, H. 2002. Organic agriculture and the environment. In: Scialabba, N. E.-H. and Hattam, C. (eds) *Organic Agriculture, Environment and Food Security*. Food and Agriculture Organization of the United Nation, Rome.

Alger, K. 1998. The reproduction of the cocoa industry and biodiversity in Southern Bahia, Brazil. *Cacao Workshop in Panama (March 30–April 2 1998)*. Smithsonian Migratory Bird Center, Washington, DC.

Allerberger, F., Fida, P., Grossgut, R., Schönbauer, M. and Würzner, H. 2003. Antibiotics in horticulture and antibiotic feed additives in animal husbandry, Austria 2002. *Wiener Klinische Wochenschrift* 115(17–18): 615–617.

Alvarez, C.E., Carraced, A.E., Iglesia E. and Martinez M.C. 1993. Pineapples cultivated by conventional and organic methods in a soil from a banana plantation. A comparative study of soil fertility, plant nutrition and yields. *Biological Agriculture and Horticulture* 9: 161–171.

APHA [American Public Health Association] 2002. *Antibiotics in U.S. Agriculture: Escalating Resistance Concerns and Policy Developments*. <http://apha.confex.com/apha/130am/techprogram/session_9107.htm>. Accessed 29 March 2005.

Aude, E., Tybirk, K., Michelsen, A., Ejrnæs, R., Hald, A.B. and Mark, S. 2004. Conservation value of the herbaceous vegetation in hedgerows – does organic farming make a difference? *Biological Conservation* 118: 467–478.

Baars, A., Klundert von de, A.F. and de Reijer, A.W.J. 1983. *Vegetatie, bodem, mineralenbalans en energieverbruik van enkele gangbare en alternatieve agrarische bedrijven in Noord-Holland*. University of Utrecht.

Baudry, J., Burel, F., Aviron, S., Martin, M., Ouin, A., Pain, G. and Thenail, C. 2003. Temporal variability of connectivity in agricultural landscapes: do farming activities help? *Landscape Ecology* 18 (3): 303–314.

Barbera, G. and La Mantia, T. 1995. Analisi agronomica energetica. Filiere atte allo sviluppo di aree collinari e montane: il caso dell'agricoltura biologica. Chironi G vo.1 RAISA-University of Palermo.

Beck T. 1991. Vergleichende Bodenuntersuchungen von konventionell und alternative bewirtschafteten Betriebsschlägen. 2. Mitteilungen II. Bodenmikrobiologische Untersuchungen. *Landwirtschaftliches Jahrbuch* 68 (4): 416–423.

Berry, N.A., Wratten, S.D., McErlich, A., and Frampton, C. 1996. Abundance and diversity of beneficial arthropods in conventional and organic carrot crops in New Zealand. *New Zealand Journal of Crop and Horticultural Science* 24: 307–313.

Bio Suisse 2001. *Richtlinien f]ü]r die Erzeugung, Verarbeitung und den Handel von Erzeugnissen aus biologischer (ökologischer) Produktion*. Bio Suisse, Basel.

Bossio, D.A., Scow, K.M., Gunapala, N., Graham, K.J. 1998. Determinants of soil microbial communities: Effects of agricultural management, season, and soil type on phospholipids fatty acid profiles. *Microbial Ecology* 10: 1–12.

Bouwman, A.F. 1996. Direct emission of nitrous oxide from agricultural soils. *Nutrient Cycling in Agroecosystems* 46: 53–70.

Bremond, J. 2002. TGRDEU as an Information system to support and establish sustainable animal production systems. In: Thompson, R. (ed.) *Proceedings of the 14th IFOAM Organic World Congress. Victoria, Canada, 21 to 28 August 2002*. Canadian Organic Growers, Ottawa. p. 40.

British Trust for Ornithology. 1995. *The Effects of Organic Farming Regimes on Breeding and Winter Bird Populations: Part1. Summary Report and Conclusions*. British Trust for Ornithology, Thetford.

Brown, R.W. 1999. Margin/field interfaces and small mammals. *Aspects of Applied Biology* 54: 203–210.

Brown, S., Swingland, K.R., Hanbury-Tenison, R., Ghillean, T., Prance, G.T. and Myers, N. 2002. Changes in the use and management of forests for abating carbon emissions: issues and challenges under Kyoto Protocol. In: Swingland, I.R. (ed.) *Capturing Carbon and Conserving Biodiversity – The Market Approach*. Earthscan, London. pp. 42–55.

Burdick, B. 1994. *Klimaänderung und Landbau – Die Agrarwirtschaft als Täter und Opfer. Ökologische Konzepte*. Stiftung Ökologie und Landbau, Bad Dürkheim.

Chadwick, D.R., Sneath, R.W., Phillips, V.R. and Pain, B.F. 1999. A UK inventory of nitrous oxide emissions from farmed livestock. *Atmospheric Environment* 33: 3345–3354.

Clark, M.S., Horwarth, W.R., Shennan, C. and Scow, K.M. 1998. Changes in soil chemical properties resulting from organic and low-input farming practices. *Agronomy Journal* 90: 662–671.

Clausen, M. and Larsen, A.B. 1997. S*mabiotoptaethed I okologiske og biodynamiske jordbrug I Ostdanmark Report*. Centre for Landscape Research, RUC, Roskilde.

Cole, C.V., Duxbury, J., Freney, J., Heinemeyer, O., Minami, K., Mosier, A., Paustian, K., Rosenberg, N., Sampson, N., Sauerbeck, D. and Zhao, Q. 1997. Global estimates of potential mitigation of greenhouse gas emissions by agriculture. *Nutrient Cycling in Agroecosystems* 49: 221–228.

Condron, L.M., Cameron, K.C., Di, H.J., Clough, T.J., Forbes, E.A., McLaren, R.G. and Silva, R.G. 2000. A comparison of soil and environmental quality under organic and conventional farming systems in New Zealand. *New Zealand Journal of Agricultural Research* 43: 443–466.

Cooke, G.W. 1967. *The Control of Soil fertility*. English Language Book Society and Crosby Lockwood Staples, London.

Cormack, W.F. 2000. *Energy use in organic farming systems*. Final report for project OF0182 for the Department for Environment, Food and Rural Affairs. ADAS, Norfolk.

Crutzen, P.J. 1981. Atmospheric chemical processes of the oxides of nitrogen, including nitrous oxide. In: Delwiche, J. (ed.) *Denitrification, Nitrification and Nitrous Oxide*. Wiley and Sons, New York. pp. 17–44.

Dabbert, S. and Piorr, A. 1999. Ökologischer Landbau. In: H.-G. and Dabbert, S. (eds) *Handbuch zum Gewässerschutz in der Landwirtschaft*. Frede, Ecomed Verlagsgesellschaft, Landsberg.

Daniel, J., Davis, J. and Grant, L. 2002. *Long-term Organic Farming Impacts on Soil Fertility*. Organic Farming Research Foundation, Santa Cruz.

David, C., Fabre, B. and Gautronneau, Y. 1996. Towards modelling the conversion of stockless farming systems to organic farming. On-farm research in the South East of France. In: Kristensen, N.H. and Hogh-Jensen, H. (eds) *New Research in Organic Agriculture, Down to Earth and Further Afield: Proceedings of the 11th International Scientific IFOAM Conference*. IFOAM, Copenhagen. pp. 23–27.

DEPA [Danish Environmental Protection Agency] 1998. *The Bichel Committee. Report from the Main Committee*. <http://www.mst.dk/udgiv/Publications/1998/87-7909-445-7/html/default_eng.htm>. Accessed 18 August 2005.

Djigma, A., Nikiema, E., Lairon, D. and Ott, P. 1990. *Proceedings of the IFOAM Seventh International Scientific Conference, 2–5. January 1989, Ouagadougou, Bourkina Faso*. IFOAM, Tholey-Theley, Germany.

Drinkwater, L.E., Letourneau, D.K., Workneh, F., van Bruggen, A.H.C. and Shennan, C. 1995. Fundamental differences between conventional and organic tomato agroecosystems in California. *Ecological Applications* 5(4): 1098–1112.

Drinkwater, L.E., Wagoner, P. and Sarrantonio, M. 1998. Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature* 396: 262–264.

Edwards, C.A., Lal, R., Madden, P., Miller, R.H. and House, G. 1990. Research on integrated arable farming and organic mixed farming in the Netherlands. In: Edwards, C.A., Lal, R., Madden, P., Miller, R.H. and House, G. (eds) *Sustainable Agricultural Systems*. Soil and Water Conservation Society, Ankeny. pp 287–296.

Edwards, A.C. and Withers, P.J.A. 1998. Soil phosphorus management and water quality: A UK perspective. *Soil Use and Management* 14, (Supplement): 124–130.

Ellemann, L., Ejrnæs, R., Reddersen, J. and Fredshavn, J.R. 2001. *Det lysåbne landskab*. National Environmental Research Institute, Roskilde.

Elmholt, S. 1996. Microbial activity, fungal abundance and distribution of Penicillium and Fusarium as bioindicators of a temporal development of organically cultivated soils. *Biological Agriculture and Horticulture* 13: 123–140.

Eltun, R. 1995. Comparisons of nitrogen leaching in ecological and conventional cropping systems. *Biological Agriculture and Horticulture* 11: 103–114.

FAO 1999. *Organic Agriculture*. Food and Agriculture Organization of the United Nations, Rome. <http://www.fao.org/unfao/bodies/COAG/COAG15/X0075E.htm>.

FAO 2001. *Soil Carbon Sequestration for Improved Land Management*. World Soil Resources Report 96, Rome.

FAO 2004. *FAOSTAT Home Page*. Food and Agriculture Organization of the United Nations, Rome. <http://faostat.fao.org/>.

Feber, R.E., Firbank, L.G., Johnson, P.J. and Macdonald, D.W. 1997. The effects of organic farming on pest and non-pest butterfly abundance. *Agriculture, Ecosystems and Environment* 64: 133–139.

Feber, R.E., Bell, J., Johnson, P.J., Firbank, L.G. and Macdonald, D.W. 1998. The effects of organic farming on surface-active spider (Araneae) assemblages in wheat in Southern England, UK. *Journal of Arachnology* 26: 190–202.

Flessa, H., Ruser, R., Dörsch, P., Kamp, T., Jimenez, M., Munch, J.C. and Beese, F. 2002. Integrated evaluation of greenhouse gas emissions from two farming systems in southern Germany. Special consideration of soil N2O-emissions. *Agriculture, Ecosystems and Environment* 91(1–3): 175–189.

Fließbach, A. 1998. Mikroorganismen in Ökoböden zeigen größere Vielfalt und höhere Abbauleistung. *Ökologie und Landbau* 106: 38–40.

Fließbach, A. and Mäder, P. 1997. Carbon source utilization by microbial communities in soils under organic and conventional farming practice. In: Insam, H. and Rangger, A. (eds) *Microbial Communities – Functional versus Structural Approaches*. Springer Verlag, Berlin. pp. 109–120.

Fließbach, A., Eyhorn, F., Mäder, P., Rentsch, D. and Hany, R. 2001. DOK long-term farming systems trial: Microbial biomass, activity and diversity affect the decomposition of plant residues. In: Rees, R., Ball, B., Campbell, C. and Watson, C. (eds) *Sustainable Management of Organic Matter*. CAB International, London. pp. 363–369.

Flores-Escuerdo, P. 2000. Conservation of a forest sanctuary in Peru by implementing an organic agriculture and sustainable development programme for small farmers in the buffer zone. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *IFOAM 2000 – The World Grows Organic: Proceedings of the 13th International IFOAM Scientific Conference*. Vdf Hochschulverlag, Zürich.

Flowerdew, J.R. 1997. Mammal biodiversity in agricultural habitats. In: Kirkwood, R.C. (ed.) *Biodiversity and Conservation in Agriculture*. British Crop Protection Council, Hampshire. pp. 25–40.

Frieben, B. 1997. Arten- und Biotopschutz durch Organischen Landbau. In: Weiger, H. and Willer, H. (eds) *Naturschutz durch ökologischen Landbau*. Deukalion, Ökologische Konzepte 95. pp. 73–92.

Frieben, B. and Köpke, U. 1996. Effects of farming systems on biodiversity. In: Isart, J. and Llerena, J.J. (eds) *Organic Farming in Land Use Systems. Proceedings of the First ENOF [European Network for Scientific Research Co-ordination in Organic Farming]*. University of Bonn, Bonn. pp. 11–21.

Fuller, R.J. 1997. Responses of birds to organic arable farming: mechanisms and evidence. *Proceedings of Brighton Crop Protection Conference, Weeds* 3: 897–906.

Garcia, C., Alvarez, C.E., Carracedo, A. and Iglesias, E. 1989. Soil fertility and mineral nutrition of a biodynamic avocado plantation in Tenerife. *Biological Agriculture and Horticulture* 6: 1–10.

Gardner, S.M. and Brown, R.W. 1998. *Review of the Comparative Effects of Organic Farming on Biodiversity*. ADAS, Wolverhampton.

Gerhardt, R.A 1997. A comparative analysis of the effects of organic and conventional farming systems on soil structure. *Biological Agriculture and Horticulture* 14: 139–157.

Gibbs, P.A., Parkinson, R.J., Fuller, M.P. and Misselbrook, T. 2000. Enhancing the effective utilisation of animal manures on farm through compost technology. In: Petchy, A.M., D'Arcy, B.J. and Frost, C.A. (eds) *Agriculture and Waste: Management for a Sustainable Future*. Scottish Agricultural College/Scottish Environment Protection Agency, Edinburgh. pp. 63–72.

Girvan, M.S., Bullimore, J., Pretty, J.N., Osborn A.M. and Ball, A.S. 2003. Soil type is the primary determinant of the composition of the total and active bacterial communities in arable soils. *Applied and Environmental Microbiology* 69: 1800–1809.

Goldstein, W.A. and Young, D.L. 1987. An agronomic and economic comparison of a conventional and a low-input cropping system in Palouse. *American Journal of Alternative Agriculture* 2: 51–56.

Gosling, P. and Shepherd, M. 2005. Long-term changes in soil fertility in organic arable farming systems in England, with particular reference to phosphorous and potassium. *Agriculture, Ecosystems and Environment* 105: 425–432.

Greenland, D. 2000. Effects on soils and plant nutrition. In: Tinker, P.B. (ed.) *Shades of Green – a Review of UK Farming Systems*. Royal Agricultural Society of England, Warwickshire. pp. 6–20.

Haas, G. and Köpke, U. 1994. Vergleich der Klimarelevanz ökologischer und konventioneller Landbewirtschaftung. In: Enquète-Kommission Schutz der Erdatmosphäre des Deutschen Bundestages (ed.) *Schutz der Grünen Erde Klimaschutz durch umweltgerechte Landwirtschaft und Erhalt der Wälder*. Economica Verlag, Bonn. pp. 92–196.

Hansen, B., Alrøe, H.F. and Kristensen, E.S. 2001. Approaches to assess the environmental impact of organic farming with particular regard to Denmark. *Agriculture, Ecosystems and Environment* 83: 11–26.

Haraldsen, T.K., Asdal, Å., Gradient, C., Nesheim, L., Ugland, T.N. 2000. Nutrient balances and yields during conversion to organic cropping systems on silt loam and clay soils in Norway. *Biological Agriculture and Horticulture* 17: 229–246.

Harris, P.J.C., Lloyd, H.D., Hofny-Collins, A.H., Barrett, H.R. and Browne, A.W. 1998. *Organic Agriculture in Sub-Saharan Africa: Farmer Demand and Potential for Development*. Henry Doubleday Research Association, Coventry.

Haygarth, P.M. and Jarvis, S.C. 1999. Transfer of phosphorus from agricultural soils. *Advances in Agronomy* 66: 195–249.

Himathongkam, S., Bahari, S., Riemann, H. and Cliver, D.O. 1999. Survival of *Escherichia coli* O157:H7 and *Salmonella typhimurium* in cow manure and cow manure slurry. *FEMS Microbiology Letters* 178: 251–257.

Hodgson, J.G., Thompson, K., Wilson, P.J. and Bogaard, A. 1998. Does biodiversity determine ecosystem function? The Ecotron experiment reconsidered. *Functional Ecology* 12: 843–848.

Hole, D.G., Perkins, A.J., Wilson, J.D., Alexander, I.H., Grice, P.V., Evans, A.D. 2005. Does organic farming benefit biodiversity? *Biological Conservation* 122 (2005): 113–130.

Hopkins, A. and Hrabe, F. 2001. Organic grassland farming and nature conservation. In: Isselstein, J., Spatz, G. and Hofmann, M. (eds) *Organic Grassland Farming*. European Grassland Federation, Witzenhausen. pp. 91–106.

Hülsbergen, K.J. and Kalk, W.D. 2001. *Energy Balances in Different Agricultural Systems – Can They be Improved?* International Fertiliser Society, York.

IFOAM 2000. *Basic Standards for Organic Production and Processing*. IFOAM, Tholey-Theley, Germany

IPCC [Intergovernmental Panel on Climate Change] 2001. Revised guidelines for national greenhouse gas inventories. In: *Agriculture, Nitrous Oxide from Agricultural Soils and Manure Management*. OECD, Paris.

Jauset, A.M., Sarasua, M.J., Avilla, J. and Albajes, R. 2000. Effect of nitrogen fertilization level applied to tomato on the greenhouse whitefly. *Crop Protection* 19(4): 255–261.

Johnson, N.C. and Pfleger, F.L. 1992. Vesicular-arbuscular mycorrhizae and cultural stress. In: Bethlenfalvay, G.J. and Lindermann, R.G. (eds) *Mycorrhizae in Sustainable Agriculture*. American Society of Agronomy, Madison. pp. 71–99.

Jordahl, J.L. and Karlen, D.L. 1993. Comparison of alternative farming systems. III. Soil aggregate stability. *American Journal of Alternative Agriculture* 8: 27–33.

Jones, P.A., Blair, A.M. and Orson, J.H. 1996. Mechanical damage to kill weeds. In: Brown, H. (ed.) *Proceedings of the Second International Weed Control Congress, Copenhagen, Denmark, 25–28 June 1996*. Department of Weed Control and Pesticide Ecology, Flakkebjerg. pp. 949–954.

Kabourakis, E. 1996. *Prototyping and Dissemination of Ecological Olive Production Systems: A Methodology for Designing and a First Step Towards Validation and Dissemination of Prototype Ecological Olive Production Systems (EOPS) in Crete*. Landbouw University Wageningen, Wageningen.

Kareiva, P. 1994. Diversity begets productivity. *Nature* 368: 686–687.

Kijlstra, A., Groot, M., Van der Roest, J., Kasteel, D. and Eijck, I. 2003. *Analysis of black holes in our knowledge concerning animal health in the organic food production chain*. Animal Sciences Group, Wageningen UR, Wageningen.

Kilcher, L. 2001. Organic agriculture in Cuba: the revolution goes green. *Journal of Agriculture in the Tropics and Subtropics* 102(2): 185–189.

Knickel, K. 2001. The marketing of Rhöngold milk: an example of the reconfiguration of natural relations with agricultural production and consumption. *Journal of Environmental Policy and Planning* 3(2): 123–136.

König, W., Sunkel, R., Necker, U., Wolff-Straub, R., Ingrisch, S., Wasner, U. and Glück, E. 1989. *Alternativer und konventioneller Landbau – Vergleichsuntersuchungen von Ackerflächen auf Lößstandorten im Rheinland*. Landesanstalt für Ökologie, Landschaftsentwicklung und Forstplanung, Nordrhein-Westfalen.

Köpke, U. 2002. Umweltleistungen des Ökologischen Landbaus. Ö*kologie and Landbau; Zeitschrift für ökologische Agrarkultur* 122: 6–18.

Kotschi, J. and Müller-Sämann, K. 2004. *The Role of Organic Agriculture in Mitigating Climate Change – A Scoping Study*. IFOAM, Bonn.

Krogh, P.H. 1994. *Microarthropods as Bioindicators. A Study of Disturbed Populations*. National Environmental Research Institute, Roskilde.

Kromp, B. 1999. Carabid beetles in sustainable agriculture: a review on pest control efficiency, cultivation impacts and enhancement. *Agriculture, Ecosystems and Environment* 74: 187–228.

Kudva, I.T., Blanch, K. and Hovde, C.J. 1998. Analysis of *Escherichia coli* O157:H7 in ovine or bovine manure and manure slurry. *Applied Environmental Microbiology* 64: 3166–3174.

Kullmann, A. 2003. Stand der Regionalvermarktung landwirtschaftlicher Produkte in den Biosphärenreservaten. In: Deutsches MAB-Nationalkomitee (ed.) *Voller Leben. UNESCO-Biosphärenreservate – Modellregionen für eine Nachhaltige Entwicklung*. Springer, Berlin. pp. 225–233.

Kus, J. and Stalenga, J. 2000. Comparison of economic and energy efficiency in ecological and conventional crop production system. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *IFOAM 2000 – The World Grows Organic: Proceedings of 13th International IFOAM Scientific Conference*. Vdf Hochschulverlag, Zürich.

Lampkin, N. 1997. Organic livestock production and agricultural sustainability. In: Isart, J. and Llerena, J.J. (eds) *Resource Use in Organic Farming. Proceedings of the Third ENOF Workshop, Ancona 5–6 June 1997*. European Network for Scientific Research Co-ordination in Organic Farming [ENOF], Barcelona. pp. 321–330.

Langer, V. 2001. The potential of leys and short rotation coppice hedges as reservoirs for parasitoids of cereal aphids in organic agriculture. *Agriculture, Ecosystems and Environment* 87(1): 81–92.

Løes, A.K. and Øgaard, A.F. 2001. Long-term changes in extractable soil phosphorous (P) in organic dairy farming systems. *Plant and Soil* 237: 321–332.

Mäder, P., Fließbach, A., Wiemken, A. and Niggli, U. 1995. Assessment of soil microbial status under long-term low input (biological) and high input (conventional) agriculture. In: Mäder, P. and Raupp, J. (eds) *Effects of Low and High External Input Agriculture on Soil Microbial Biomass and Activities in View of Sustainable Agriculture*. pp. 24–38.

Mäder, P., Pfiffner, L., Fließbach, A., von Lützow, M. and Munch, J.C. 1996. Soil ecology – the impact of organic and conventional agriculture on soil biota and its significance for soil fertility. In: Troels, V. (ed.) *Fundamentals of Organic Agriculture. Proceedings of the 11th IFOAM Scientific Conference*. IFOAM, Tholey-Theley, Germany. pp. 24–46.

Mäder, P., Fließbach, A., Dubois, D., Gunst, L., Fried, P. and Niggli, U. 2002. Soil fertility and biodiversity in organic farming. *Science* 296: 1694–1697.

Maidl, F.X., Demmel, M. and Fischbeck, G. 1988. Vergleichende Untersuchungen ausgewählter Parameter der Bodenfruchtbarkeit auf konventionell und alternativ bewirtschafteten Standorten. *Landwirtschaftliche Forschung* 41 (3–4): 231–245.

McNeely, J.A. and Scheer, S.J. 2001. *Common Ground, Common Future. How EcoAgriculture can help feed the World and Save Wild Biodiversity*. IUCN/Future Harvest, Gland.

Meuser, H. 1989. *Einfluss unterschiedlicher Düngungsformen auf Boden und Pflanze, Untersuchungen zum Wasser- und Nährstoffhaushalt des Bodens und zum Pflanzenwachstum*. Institut für Landschaftsentwicklung und Umweltforschung der TU Berlin, Berlin.

Miller, K., Chang, E. and Johnson, N. 2001. *Defining Common Ground for the MesoAmerican Biological Corridor*. World Resource Institute, Washington DC.

Nabhan, G.P. 1998. *Pollinator Redbook. Volume One. Global List of Threatened Vertebrate Wildlife Species Serving as Pollinators for Crops and Wild Plants*. Arizona-Sonora Desert Museum and Forgotten Pollinators Campaign Monographs, Tucson.

Neale, S. 1998. *Modelling Earthworm Communities, Comparing Organic with Conventional Arable Rotations. EFRC Research Bulletin* 34(2): 7–9.

Necker, U., Kamann and Fründ, H.C. 1992. Bodenbiologische Untersuchungen auf konventionell und organisch-biologisch bewirtschafteten Ackerflächen. *VDLUFA-Schriftenreihe* 35: 563–566.

Nguyen, M.L., Haynes, R.J. and Goh, K.M. 1995. Nutrient budgets and status in three pairs of conventional and alternative mixed cropping farms in Canterbury, New Zealand. *Agriculture, Ecosystems and Environment* 52: 149–162.

Nguyen, M.L. and Haynes, R.J. 1995. Energy and labour efficiency for three pairs of conventional and alternative mixed cropping (pasture-arable) farms in Canterbury, New Zealand. *Agriculture, Ecosystems and Environment* 52: 163–172.

Nicholson, F., Chambers, B., Hutchinson, M., Moore, T., Nicholson, N. and Hickman, G. 2002. Farm manures: assessing and managing the risks of pathogen transfer into the food chain. In: *7th European Biosolids and Organic Residual Conference, Wakefield, UK*.

Niggli, U., Alföldi, T., Mäder, P., Pfiffner, L., Spiess, H. and Besson, J.-M. 1995. DOK-Versuch, vergleichende Langzeit-Untersuchungen in den drei Anbausystemen biologisch-Dynamisch, Organisch-biologisch und Konventionell. VI. Synthese, 1. und 2. Fruchtfolgeperiode. *Sonderheft DOK* 4: 1–34.

Nocquet, J., David, C. and Gautronneau, Y. 1996. *A Farming System Environmental Assessment Applied on Organic Farms and Farms in Conversion*. European Society for Agronomy, Wageningen.

Oehl, F., Oberson, A., Tagmann, H.U., Besson, J.M., Dubois, D., Mäder, P., Roth, H.R., Frossard, E. 2002. Phosphorous budget and phosphorous availability in soils under organic and conventional management. *Nutrient Cycling in Agroecosystems* 62: 25–35.

OECD 1997. *Environmental Indicators for Agriculture*. Organisation for Economic Cooperation and Development, Paris.

OECD 2000. *Environmental Indicators for Agriculture. Volume 3, Methods and Results*. Organisation for Economic Cooperation and Development, Paris.

Oldeman, L.R. 1994. The global extent of soil degradation. In: Greenland, D.J. and Szabolcs, L. (eds) *Soil Resilience and Sustainable Land Use*. CAB International, Wallingford. pp. 99–118.

Pain, B.F., van der Weerden, T.J., Chambers, B.J., Phillips, V.R. and Jarvis, S.C. 1998. A new inventory for ammonia emissions from UK agriculture. *Atmospheric Environment* 32: 309–313.

Palm, C.A., Woomer, P.L., Alegre, J., Arevalo, L., Castilla, C., Cordeiro, D.G., Feigl, B., Hairiah, K., Kotto-Same, J., Mendes, A., Moukam, A., Murdiyarso, D., Njomgang, R., Parton, W.J., Riese, A., Rodrigues, V., Sitompul, S.M. and Noordwijk, M. 2000. *Climate Change Working Group Final Report, Phase II: Carbon Sequestration and Trace Gas Emissions in Slash-and-Burn and Alternative Land Uses in the Humid Tropics*. International Center for Research in Agroforestry, Nairobi.

Parrott, N. and Marsden, T. 2002. *The Real Green Revolution. Organic and Agroecological Farming in the South*. Greenpeace Environmental Trust, London.

Peeters, A. and van Bol, V. 1993. Study of the limits and potential of systems and techniques of integrated and alternative agriculture. In: Peeters, A. and Van Bol, V. (eds) *Research Report EU – Contract 28/01/1991 number 8001-CT90-0003*. Laboratoire d'Écologie des Prairies, Louvain-La-Neuve p. 47.

Penfold, C. 2000. *Phosphorous Management in Broadacre Organic Farming Systems*. Rural Industries Research and Development Corporation, Barton.

Pennanzi, A. 1996. Un nuovo paesaggio con l'agricoltua pulita. *Bioagricultura* 42: 3.

Persson, J. 1994. Mullhaltsförändringar i olika odlingssytem. In: Höök, K. and Sandström, M. (eds) *Edologiskt lantbruk, konferens Ekologiskt lantbruk*. Swedish University of Agricultural Sciences, Uppsala.

Petersen, S.O., Debosz, K., Schønning, P., Christensen, B.T. and Elmholt, S. 1997. Phospholipid fatty acid profiles and C availability in wet-stable macro-aggregates from conventionally and organically farmed soils. *Geoderma* 78: 181–196.

Pfiffner, L. 1997. Welchen Beitrag leistet der ökologische Landbau zur Förderung der Kleintierfauna? In: Weiger, H. and Willer , H. (eds) *Naturschutz durch ökologischen Landbau. Ökologische Konzepte 95*. Deukalion Verlag, Holm. pp. 93–120.

Pfiffner, L. and Luka, H. 1999. Overwintering of arthropods in soils of arable fields and adjacent semi-natural habitats. *Agriculture, Ecosystems and Environment* 78(3): 215–222.

Pfiffner, L. and Mäder, P. 1997. Effects of bio-dynamic, organic and conventional production systems on earthworm populations. *Biological Agriculture and Horticulture* 15: 3–10.

Pfiffner, L. and Niggli, U. 1996. Effects of bio-dynamic, organic and conventional farming on ground beetles and other epigaeic arthropods in winter wheat. *Biological Agriculture and Horticulture* 12: 353–364.

Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Christ, S., Shpritz, L., Fitton, L., Saffourri, R. and Blair, R. 1995. Environmental and economic cost of soil erosion and conservation benefits. *Science* 267: 1117–1120.

Piorr, A. and Werner, W. 1998. *Nachhaltige landwirtschafliche Produktionssysteme im Vergleich: Bewertung anhand von Umweltindikatoren*. Verlags Union Agrar, Frankfurt.

Pomares, F., Olmos, J., Estela, M. and Tarazona F. 1994. Fertilidad de la tierra y estado nutritivo de cítricos en cultivo ecológico. *Actas del primer congreso de la Sociedad Española de Agricultura Ecologica, Toledo*.

Pretty, J.N. and Ball, A. 2001. *Agricultural Influences on Carbon Emissions and Sequestration: A review of Evidence and the Emerging Trading Options*. Centre for Environment and Society, University of Essex.

Pryor, A.W. 2000. Organic certified products as a basis for sustainable management of biological reserves: 'Case study of Guayaki biological reserve in Paraguay'. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *IFOAM 2000 – The World Grows Organic: Proceedings of 13th International IFOAM Scientific Conference*. Vdf Hochschulverlag, Zürich.

Raupp, J. 1995. Main effects of various organic and mineral fertilisation on soil organic matter turnover and plant growth. *Proceedings of the First Meeting of the Concerted Action AIR3-CT94-1940, Fertilisation Systems in Organic Farming*. Institute of Biodynamic Research, Darmstadt.

Reddersen, J. 1997. The arthropod fauna of organic versus conventional cereal fields in Denmark. *Biological Agriculture and Horticulture* 15: 61–71.

Reenberg, A. and Baudry, J. 1999. Land use and landscape changes – the challenge of comparative analysis of rural areas in Europe. In: Krönert, R., Baudry, J., Bowler, I.R. and Reenberg, A. (eds) *Land Use Changes and Their Environmental Impact in Rural Areas in Europe*. Man and the Biosphere Series Volume 24. UNESCO, Paris, and Parthenon Publishing, Carnforth.

Refsgaard, K., Halberg, N. and Kristensen, E.S. 1998. Energy utilisation in crop and dairy production in organic and conventional livestock production systems. *Agricultural Systems* 57: 599–630.

Reganold, J.P. 1988. Comparison of soil properties as influenced by organic and conventional farming systems. *American Journal of Alternative Agriculture* 3: 144–155.

Reganold, J.P. 1995. Soil quality and farm profitability studies of biodynamic and conventional farming. In: Cook, H.F. and Lee, H.C. (eds) *Soil Management in Sustainable Agriculture*. Wye College Press, Wye. pp. 1–11.

Reganold, J.P., Palmer, A.S., Lockhart, J.C. and Macgregor, A.N. 1993. Soil quality and financial performance of biodynamic and conventional farms in New Zealand. *Science* 260: 344–349.

Reilly, J., Baethgen, W., Chege, F.E., van de Geijn, S.C., Erda, L., Iglesias, A., Kenny, G.J., Patterson, D., Rogastik, J., Rotter, R., Rosenzweig, C., Sombroek, W. and Westbrook, J.

1996. Agriculture in a changing climate: impacts and adaptation. In: Watson, R.T., Zinyowera, M.C. and Moss, R.H. (eds) *Climate Change 1995, Impacts Adaptations and Mitigations of Climate Change: Scientific-Technical and Analyses. The Second Assessment Report of the Intergovernmental Panel on Climate Change: Contribution of Working Group II*. Cambridge University Press, Cambridge. pp. 427–467.

Reiter, K. and Krug, A. 2003. Naturschutz und Ökologischer Landbau – auch zukünftig ein win-win-Modell. In: *7. Wissenschaftstagung zum Ökologischen Landbau, Ökologischer Landbau der Zukunft, Wien, 24–26 Februar 2003, 157–160*. Universität für Bodenkultur Wien, Institut für Ökologischen Landbau, Vienna.

Rhône-Poulenc 1997. *Rhône-Poulenc Agriculture. Farm Management Study. 7th Annual Report*. Rhône-Poulenc, Ongar.

Rice, R. and Ward, J. 1996. *Coffee, Conservation and Commerce in the Western Hemisphere*. Smithsonian Migratory Bird Center and Natural Resources Defence Council, Washington DC.

Rinne, S.-L., Sippola, J. and Simojoki, P. 1993. Omavaraisen viljelyn vaikutus maan ominaisuuksiin. Maatalouden tutkimuskeskus. *Tiedote* 4.

Roelofs, J.G.L. and Houdijk, A.L.M. 1991. Ecological effects of ammonia. In: Nielson, V.C., Pain, B.F. and Hartung, J. (eds) *Ammonia and Odour Emission from Livestock Production*. Elsevier, Barking. pp. 10–16.

Scheller, E. and Vogtmann, H. 1995. Case studies on nitrate leaching in arable fields of organic farms. *Biological Agriculture and Horticulture* 11: 91–102.

Schönwiese, C. 1995. *Klimaänderungen: Daten , Analysen, Prognosen*. Berlin.

Schwertmann, U., Vogl, W. and Kainz, M. 1990): *Bodenerosion durch Wasser: Vorhersage des Abtrags und Bewertung von Gegenmaßnahmen*. Ulmer, Stuttgart.

Scialabba, N.E.-H. and Hattam, C. (eds) 2002. *Organic Agriculture, Environment and Food Security*. Food and Agriculture Organization of the United Nations, Rome.

Scialabba, N.E.-H., Gande, C. and Henatsch, C. 2002. *Organic Agriculture and Genetic Resources for Food and Agriculture*. FAO, Rome.

Scow, K.M., Somasco, O., Gunapala, N., Lau, S., Venette, R., Ferris, H., Miller, R. and Shennan, C. 1994. Transition from conventional to low-input agriculture changes soil fertility and biology. *California-Agriculture* 48: 20–26.

Scullion, J., Eason, W.R. and Scott, E.P. 1998. The effectivity of arbuscular mycorrhizal fungi from high input conventional and organic grassland and grass-arable rotations. *Plant and Soil* 204: 243–254.

Scullion, J., Neale, S. and Philipps, L. 2002. Comparisons of earthworm populations and cast properties in conventional and organic arable rotations. *Soil Use and Management* 18: 293–300.

Shannon, D., Sen, A.M. and Johnson, D.B. 2002. A comparative study of the microbiology of soils managed under organic and conventional regimes. *Soil Use and Management* 18: 274–283.

Shepherd, M., Bhogal, A., Phillips, L., Rayns, F., Lennartsson, M., Jackson, L. and Pain, B. 1999. *The Environmental Implications of Manure Use in Organic Agriculture*. ADAS, Wolverhampton.

Shepherd, M., Pearce, B., Cormack, B., Philipps, L., Cuttle, S., Bhogal, A., Costigan, P. and Unwin, R. 2003. *An Assessment of the Environmental Impacts of Organic Farming*. ADAS, Wolverhampton.

Siegrist, S., Schaub, D., Pfiffner, L. and Mäder, P. 1998. Does organic agriculture reduce soil erodibility? The results of a long-term field study on loess in Switzerland. *Agriculture, Ecosystems and the Environment* 69: 253–264.

Sims, J.T., Simard, R.R., Joern, B.C. 1998. Phosphorus loss in agricultural drainage: historical perspective and current research. *Journal of Environmental Quality* 27(2): 277–293.

Smeding, F.W. 1992: *Mogelijkeden voor de bescherming von akkerkruiden in de biologische landbouw*. Wageningen.

Soil Association 2001. Briefing paper – Biodiversity and genetic engineering. Soil Association, Bristol.

Stobbelaar, D.J. and van Mansvelt, J.D. 2000. The process of landscape evaluation. *Agriculture, Ecosystems and Environment* 77: 1–15.

Stockdale, E.A., Lampkin, N.H., Hovi, M., Keatinge, R., Lennartsson, E.K.M., Macdonald, D.W., Padel, S., Tattersall, F.H., Wolfe, M.S. and Watson, C.A. 2001. Agronomic and environmental implications for organic farming systems. *Advances in Agronomy* 70: 261–327.

Stolton, S. 1997. Fighting drought in Kenya. *Ecology and Farming* 19.

Stolton, S. 2002. *Biodiversity and Organic Agriculture*. IFOAM, Tholey-Theley, Germany.

Stolton, S. and Dudley, N. 2000a. The use of certification of sustainable management systems and their possible application to protected area management. In: *The Conference Beyond the Trees, 8–11 May 2000 Bangkok, Thailand*. <http://www.panda.org/forests 4life/spotlights/trees/bt-sdpaper.htm>.

Stolton, S. and Dudley, N. 2000b. Organic agriculture in protected areas: creating partnerships for development. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *IFOAM 2000 – The World Grows Organic: Proceedings of 13th International IFOAM Scientific Conference*. Vdf Hochschulverlag, Zürich.

Stolton, S. and Geier, B. 2002. *The relationship between biodiversity and organic agriculture: defining appropriate policies and approaches for sustainable agriculture*. IFOAM, Tholey-Theley, Germany.

Stolton, S., Geier, B. and McNeely, J.A. (eds) 2000. The Relationship between Nature Conservation, Biodiversity and Organic Agriculture. IFOAM, Tholey-Theley, Germany.

Stolze, M. 1998. *Organisationsformen ostdeutscher landwirtschaftlicher Großbetriebe nach der Umstellung auf ökologischen Landbau*. Agrimedia, Bergen/Dumme.

Stolze, M., Piorr, A., Häring, A. and Dabbert, S. 2000. *The Environmental Impacts of Organic Farming in Europe*. University of Hohenheim, Stuttgart-Hohenheim.

Stopes, C. and Philipps, L. 1992. Nitrate leaching from organic farming systems. *Aspects of Applied Biology* 30: 167–174.

Sunderland, K.D. and Samu, F. 2000. Effects of agricultural diversification on the abundance, distribution, and pest control potential of spiders: a review. *Entomologia Experimentalis et Applicata* 95: 1–13.

Sundrum, A. and Geier, U. 1996. Beurteilung von Strategien zur Minimierung von Methan und Kohlendioxidemissionen aus der Tierhaltung. In: Köpke, U. and Haas, G. (eds) *Umweltrelevanz des Ökologischen Landbaus. Landbauforschung Völkenrode. Sonderheft 175*. pp. 119–146.

Thenail, C. and Baudry, J. 2004. Variation of farm spatial land use pattern according to the structure of the hedgerow network (bocage) landscape: a case study in northeast Brittany. *Agriculture, Ecosystems and Environment* 101(1): 53–72.

Tilman, D. 1997. Biodiversity and ecosystem functioning. In: Daily, G. (ed.) *Nature Services; Societal Dependence on Natural Ecosystems*. Island Press, Washington DC. pp. 93–112.

Tilman, D. 1998. The greening of the green revolution. *Nature* 396: 211–212.

Tisdale, S.L., Nelson, W.L., Beaton, J.D. and Havlin, J.L. 1993. *Soil Fertility and Fertilizers*. Macmillan, New York.

Tress, B. 1999. *Landwirtschaft – Landschaft. Umstellungspotential und landschaftliche Konsequenzen der ökologischen Landwirtschaft in Dänemark*. PhD thesis, Institut for Geografi og Internationale udviklingsstudier, Roskilde Universitetscenter, Roskilde.

Tybirk, K, Alrøe, H.F., Frederiksen, P. 2004. Nature quality in organic farming: A conceptual analysis of consideration and criteria in a European context. *Journal of Agricultural and Environmental Ethics* 17(3): 249–274.

UNCTAD [United Nations Conference on Trade and Development] 2003. *Organic Fruit and Vegetables from the Tropics. Market, Certification and Production Information for Producers and International Trading Companies*. UNCTAD, Geneva.

Unwin, R.J., Bell, B., Shepherd, M., Webb, J., Keatinge, R. and Bailey, S. 1995. *The Effect of Organic Farming Systems on Aspects of the Environment*. MAFF, London.

Van Elsen, T. 1997. Landschaftsentwicklung – eine Zukunftsaufgabe für die ökologische Landwirtschaft? In: Köpke, U. and Eisele, J.-A. (eds) *Beiträge zur 4. Wissenschaftstagung zum Ökologischen Landbau*. Rheinische Friedrich-Wilhelms-Universität zu Bonn, Bonn.

Van Elsen, T, 2000. Species diversity as a task for organic agriculture in Europe. *Agriculture, Ecosystems and Environment* 77: 101–109.

Van Elsen, T. 2001. Ansätze zur Landschaftsentwicklung durch Landwirtschaft – das Beispiel Marbachstal/Kassel. In: Reents, H.J.(ed.) *Von Leit-Bildern zu Leit-Linien: Beiträge zur 6. Wissenschaftstagung zum Ökologischen Landbau*. Köster, Berlin. pp. 349–352.

Van Emden, H.F. 2003. Conservation biological control: from theory to practice. In: Van Driesche, R. (ed.) *Proceedings of the First International Symposium on Biological Control of Arthropods, Honolulu, Hawaii, 14–18 January 2002*. USDA Forest Service, Morgantown, West Virginia. pp. 199–208.

Van Mansvelt, J.D., Stobbelaar, J. and Hendriks, K. 1998. Comparison of a landscape feature in organic and conventional farming systems. *Landscape and Urban Planning* 41: 209–227.

Van Mansvelt, J.D. and van der Lubbe, M.J. 1999. *Checklist for Sustainable Landscape Management: Final Report of the EU Concerted Action AIR3-CT93-1210: The Landscape and Nature Production Capacity of Organic-Sustainable Types of Agriculture*. Elsevier, Amsterdam.

Van Zwieten, L., Merrington, G. and Van Zwieten, M. 2004. Review of impacts on soil biota caused by copper residues from fungicide application. In: Singh, B. (ed.) *SuperSoil2004: Third Australian New Zealand Soils Conference, University of Sydney, Australia, 5–9 December 2004*. The Regional Institute, Gosford. pp. CD-ROM.

Verkerk, R.H.J., Leather, S.R., Wright, D.J. 1998. The potential for manipulating crop-pest-natural enemy interactions for improved insect pest management. *Bulletin of Entomological Research* 88: 493–501.

Vizioli, V. 1998. La fertilizzazione organica in agricoltura biologica. *Mediterraneo* 4: 8.

Vreeland, J.M. 2000. Systems and genetic diversity in the high jungle of Peru. In: Stolton, S., Geier, B. and McNeely, A. (eds) *The Relationship Between Nature Conservation, Biodiversity and Organic Agriculture. Proceedings of an International Workshop Held in Vignola, Italy 1999*. IFOAM, IUCN, AIAB. pp. 41–42.

Wascher, D.M. (ed.) 2000. *Agri-environmental Indicators for Sustainable Agriculture in Europe*. European Centre for Nature Conservation, Tilburg.

Watson, C.A., Bengtsson, H., Ebbesvik, M., Løes, A.K., Myrbeck, A., Salomon, J., Stockdale, E.A. 2002. A review of farm-scale nutrient budgets for organic farms as a tool for management of soil fertility. *Soil Use Management* 18: 264–273.

Watson R.T., Zinyowera M.C., Moss R.C. 1996. *Technologies, Policies and Measures for Mitigating Climate Change. November 1996, Paper Prepared under the Auspices of IPCC Working Group II*. US Global Change Research Information Office, Columbia University, New York.

Welsh, J.P., Tillett, N., Home, M. and King, J.A 2002. *A Review of knowledge: Inter-row Hoeing and its Associated Agronomy in Organic Cereal and Pulse Crops*. Report for Project OF0312 to the Department for Environment, Food and Rural Affairs. Elm Farm Research Centre, Newbury.

Werner, M.R. 1997. Soil quality characteristics during conversion to organic orchard management. *Applied Soil Ecology* 5: 151–167.

Whalen, J.K., Parmalee, R.W. and Edwards, C.A. 1998. Population dynamics of earthworms communities in corn agroecosystems receiving organic and inorganic fertiliser amendments. *Biology and Fertility of Soils* 27: 400–407.

Wickramasingeh, L.P., Harris, S., Jones, G., Vaughan, N. 2003. Bat activity and species richness on organic and conventional farms: impact of agricultural intensification. *Journal of Applied Ecology* 40: 984–993.

Yardim, E.N. and Edwards, C.A. 2003. Effects of organic and synthetic fertilizer sources on pest and predatory insects associated with tomatoes. *Phytoparasitica* 31(4): 324–329.

Yeates, G.W., Bardgett, R.D., Cook, R., Hobbs, P.J., Bowling, P.J., Potter, J.F. 1997. Faunal and microbial diversity in three Welsh grassland soils under conventional and organic management regimes. *Journal of Applied Ecology* 34: 453–470.

Younie, D. and Watson, C.A. 1992. Soil nitrate-N levels in organically and intensively managed grassland systems. *Aspects of Applied Biology* 30: 235–238.

Zarea, A., Koocheki, A., and Nasiri, M. 2000. Energy efficiency of conventional and ecological cropping systems in different rotations. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *IFOAM 2000 – The World Grows Organic: Proceedings of 13th International IFOAM Scientific Conference*. Vdf Hochschulverlag, Zürich.

Special topic 4

Tillage: how bad is it in organic agriculture?

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Introduction

Soil tillage is often perceived to exert negative effects on organic farming systems. This perception likely stems from the consideration that tillage can deteriorate soil structure, disrupt ecological niches for soil biota (e.g. earthworms and vesicular-arbuscular mycorrhizae) that have positive ecological functions in agroecosystems, enhance soil organic matter (SOM) mineralisation and impair SOM build up, increase risks of nutrient losses to the environment and of soil erosion and ultimately contribute to soil fertility loss and soil quality degradation. However, it would be incorrect to claim that soil tillage *per se* is the cause of these negative effects. Indeed, such effects are more appropriately associated with repeatedly wrong technology application, such as the blanket use of deep mouldboard ploughing regardless of crop and environmental context, as it has been the typical long-term situation in conventional systems, like continuous wheat cropping in Southern Europe (Bàrberi and Lo Cascio 2001).

As the negative effects of tillage are often associated with conventional agriculture, and as one of the main goals of organic agriculture is to counteract and/or prevent negative aspects related to conventional systems management, it would seem logical to always associate organic systems management with tillage reduction. The aim of this chapter is to challenge this dogma through a reasoned analysis of the pros and cons of tillage in organic agriculture based on the rather scant scientific literature available, and underlining the need to conceptualise tillage management in a cropping system and environmental context. Lastly, differences between the expected effects of tillage management in conventional and organic systems will be discussed.

When tillage is important in organic agriculture

Organic systems rely on the application of organic amendments, green manures and other organic matter sources with the dual purpose of:

1 building up soil fertility through an increase in SOM quantity and quality; and
2 supplying adequate amounts of nutrients, especially nitrogen (N), to sustain crop growth and productivity.

This indirect approach to crop fertilisation, which clearly reflects the preventive, long-term nature of agronomic recommendations set forth in organic systems (IFOAM 2005), increases the difficulty of meeting timely crop nutrient requirements, especially in environments characterised by high climatic variation. For example in Wales, Adams and Jan (1999) observed that the optimum date (August–September) of incorporation of a clover ley differed between years due to different rainfall patterns, which affected nitrogen (N) leaching during the germination and early growth phases of the subsequent ryegrass crop. In temperate climates, some degree of biomass incorporation by tillage is usually required to trigger SOM mineralisation and consequent nutrient release, especially in stockless organic arable crop rotations (Schmidt *et al*. 1999). Drinkwater *et al*. (2000) showed that N release from vetch residues was quicker when incorporated by chisel or mouldboard ploughing as compared to mow-killed vetch with residues left on soil surface. In addition to crop growth and yield, biomass incorporation in the soil facilitated weed control and reduced soilborne pest and pathogen loads in several cases (Liebman and Davis 2000). However, this effect is controversial since in south-western Japan, Hidaka (1997) observed that the abundance of *Sogatella furcifera* (Horvath) (a rice insect pest) was much reduced while its most important predators (sedentary lycosids) increased in lower-input organic farming systems based upon no tillage and winter legume surface mulch compared to traditionally managed organic paddy rice. Similarly, van Bruggen and Termorshuizen (2003) claimed that SOM conservation through reduced tillage application is a key element of integrated disease management because it favours the establishment of more equilibrated soil microbial communities.

However, the main reason why some soil tillage is needed in organic systems is to facilitate weed management. Most studies that have analysed weed community dynamics following conversion from conventional to organic agriculture have shown increased weed problems (Belde *et al*. 2000), especially when reduced or no-till systems were adopted compared to organic plough-based systems (Gruber *et al*. 2000). In particular, no-till increases the abundance of grasses, perennial weeds and anomochorous (wind-dispersed) species (Zanin *et al*. 1997). These species are particularly favoured by reduced soil disturbance because of a lack of primary dormancy, vegetative propagation and possession of ecological traits favourable to site recolonisation, respectively. The same effect is usually observed in reduced or no-till conventional systems, but direct (e.g. mechanical, thermal) weed control methods applied in organic systems are usually less effective than chemical herbicides. This reduces the selection pressure against weeds and hence the risk of undesired evolution in weed community composition (Bàrberi 2002), but accelerates the build up of weed seedbank densities that can more often turn into competitive weed stands. Also, minimum tillage coupled with organic fertilisation can increase the abundance of troublesome arable weeds like *Galium aparine* (McCloskey *et al*. 1996). It can then be assumed that, at least in temperate regions, management of organic systems without returning to tillage from time to time would soon become unsustainable due to intolerable weed pressure, although this negative effect could be retarded by the adoption of an appropriately diversified crop rotation (Rasmussen *et al*. 1999).

When over-reliance on tillage can be troublesome

Whereas tillage may be necessary in organic systems, there are other cases in which the negative effects can overcome the benefits. This is the case in soils highly susceptive to erosion (e.g. sloping soils) and compaction (e.g. silty or heavy clayey soils). Pulleman *et al*. (2003) observed that soil compaction, although lower than in a conventionally managed arable crop rotation, was all but negligible in an organically managed one. It is then incorrect to assume that amelioration of soil fertility parameters, as typical of organic management (see *Conceptualising tillage management in organic agriculture*), would always prevent these soils from undergoing physical (e.g. structural) damage caused by overweighing machinery, especially when they have excess soil moisture content and are exposed to traffic.

Another case in which tillage may be deleterious is when the climate is conducive to high SOM mineralisation and thus to soil fertility depletion (e.g. in the humid tropics). Again, this effect is not exclusive to organic systems; nevertheless, in such conditions any soil disturbance, including mechanical weed control, should be avoided since it greatly accelerates microbial degradation of SOM. For this reason, organic systems management in these environments should always rely upon the regular application of organic amendments, surface mulching and conservation tillage practices (Eyhorn *et al*. 2002). However, in this situation even these practices would be unlikely to increase SOM content considerably. It is well known that SOM depletion makes soils frailer and hence more prone to erosion regardless of their innate erodibility, thus any application of tillage under tropical conditions should always be carefully considered. In the arid Sudano–Sahelian area, however, regular manure application can partly counteract the negative effects of tillage on SOM content (Mando *et al*. 2005).

In contrast, organic farmers in cold temperate regions could have the opposite problem (i.e. insufficient nutrient release due to slow SOM mineralisation), thus some degree of tillage may be needed to aerate the soil and thus enhance microbial activity. Besides considering the already mentioned problems (e.g. pathogen and weed population build up), reduced tillage and/or mulch-based organic systems would probably retard crop emergence and early growth because of the well-known negative correlation between mulch and crop residue thickness and the temperature of surface soil layers.

Environmental impact of tillage

In general, the potential environmental impact of organic plough-based systems is assumed to be higher than those of systems based on non-inversion tillage, since the former are more detrimental to populations of beneficial arthropods and earthworms, and may increase nitrate leaching, pest and disease problems (see *When tillage is important in organic agriculture*).

However, appropriate crop rotation planning and timing of soil cultivation can greatly reduce N leaching in organic systems. In the United Kingdom (UK), Stopes *et al*. (1996) observed that about one-third of the total N accumulated by a red clover green manure crop (above-ground biomass) was lost by leaching following cultivation in September before sowing a winter wheat crop. In contrast, delayed cultivation until the next spring substantially reduced nitrate leaching because the soil was protected by clover residues throughout the rainy winter season.

Deep plough-based organic systems may increase energy consumption in agroecosystems (Kouwenhoven *et al*. 2002), which is another important indicator of environmental impact. In contrast, mulch-based systems and systems in which manure is left on the soil surface or is shallowly incorporated would enhance N volatilisation losses to the atmosphere. However, compared to ploughing, shallow incorporation (rotovation) of an organic ley did not significantly increase cumulative nitrous oxide (N_2O) emissions from soil (van der Weerden *et al*. 2000).

There is little scientific literature available on the effect of different tillage systems on biodiversity in organic agriculture. Usually, the literature refers to comparisons between conventional and organic systems in which almost invariably, biodiversity indicators (e.g. floral, faunal, habitat, landscape diversity) show more favourable values for organic than for conventional systems (Stolze *et al*. 2000). Organic systems may also help preserve endangered wild flora species which in conventionally managed agroecosystems would otherwise be shifted towards the brink of extinction (Albrecht and Mattheis 1998). However, these types of studies often do not consider that the functional value of biodiversity indicators (e.g. field margin complexity and landscape diversification) may be different between conventional and organic systems because the aims of these systems differ. In organically grown wheat, Petersen (2002) showed that tillage technique (mouldboard ploughing v. chiselling) significantly affected the distribution of Collembola populations over soil depth, but the functional implications of these differences were unclear. In studies comparing the effect of alternative tillage systems on biodiversity in organic systems it would be desirable to include parameters expressing the quantity beside the quality of indicators and weigh their positive and negative functions accordingly. For example, the value of a biodiversity indicator such as 'spontaneous vegetation' (i.e. potential weeds) should be based on both quality (e.g. species richness, evenness) and quantity (e.g. density, biomass) parameters, to also express the negative functions (weediness, competition) potentially associated with them (Bàrberi 2002).

Conceptualising tillage management in organic agriculture

Tillage can have either a positive or negative connotation in organic agriculture depending on the specific context, and especially on the climatic region where agriculture is conducted. Socioeconomic and cultural factors may also influence organic farmers' attitude towards tillage; here however, only some agronomically based concepts will be discussed. To date, surprisingly few scientific investigations have tried to address the tillage issue with such a global approach.

Since SOM build up or conservation is crucial to the success of organic systems, an apparent SOM budget (inputs minus outputs) may be proposed as a reference indicator to guide tillage choice and management in different environments (Table 1). If the SOM budget is negative, then increased biomass supply (e.g. through cover crop use, cautious crop residue management) or recourse to mixed farming systems should be coupled with minimum soil disturbance to reduce SOM mineralisation. If the SOM budget is neutral or slightly positive, then no specific restrictions should be applied to tillage, besides those based on agronomic common sense (e.g. tillage avoidance close to expected heavy rainfall to reduce the risk of nitrate leaching and wherever possible, abandonment of heavy machinery use to protect soil structure). If the SOM budget is decidedly positive (e.g. in some farming systems of cold temperate regions with large amounts of soil-applied farmyard manure or compost) (Asdal and Bakken 1999), cautious tillage management is again required to prevent groundwater nitrate pollution. This problem, frequent in Northern European organic farming systems (Eriksen *et al.* 2004), has driven research towards the development and application of reduced tillage in organic systems. Much of this work has been done in Denmark. Henriksen *et al.* (2000) studied the application of the Kemink exact soil tillage system to sugar beet production. The Kemink system is based on use of non-inversion soil tillage, subsoiling, ridges, controlled traffic and low manure input. The top 35–40 cm of the soil is loosened by a winged subsoiler before and/or during and after the growing season. Kemink subsoiling prior to sowing stimulated sugar beet growth and increased root yield by 7%, probably because of better soil tilth formation and increased N mineralisation. In contrast, root yield diminished when the Kemink subsoiler was passed post-emergence, because of the likely indirect and/or direct damage caused to growing beet roots.

However, the effect of subsoiling on soil tilth is controversial even in the same environment (i.e. Denmark). Munkholm *et al.* (2001b) showed that, compared to mouldboard ploughing at 22 cm depth (MP), subsoiling at 35 cm (S) + rotovation (S + R) resulted in a poorer soil tilth in the surface layer (i.e. higher soil strength and a lower ease of fragmentation and friability index), although it loosened the plough pan (the soil penetration resistance measured at field capacity was about 1800 kPa in MP and <1000 kPa in S + R). Cropping system structure, incorporating the inclusion of a grass ley in the rotation or differences in manure application

Table 1 Expected potential values of soil and cropping system quality indicators influenced by soil tillage in different environments
SOM = soil organic matter, + + very high, + high, – low, – – very low.

	Environment				
Indicator	**Tropical, humid**	**Temperate, warm**	**Temperate, cold**	**Semi-arid, warm**	**Semi-arid, cold**
Cropping system diversification[A]	+ +	+	+	– –	– –
SOM mineralisation	+ +	+	–	+	– –
Organic matter (biomass) production	+ +	–	+	– –	– –
N volatilisation	+ +	+	+	–	–
Soil compaction	+	+	–	+	+
Soil tilth	–	–	+	–	–
Soil erosion	+ +	+	–	+	+
Soil water retention	–	–	+	– –	– –
Soil nutrient uptake	+ +	+	–	–	– –
Nitrate leaching	+	–	+ +	– –	–
Pests, diseases and weeds	+ +	+	+ +	–	–

[A] Includes the possibility to grow cover crops and intercrops.

rates, had a more pronounced effect on soil mechanical characteristics than tillage *per se* (Munkholm *et al*. 2001a). For example, cropping systems with higher organic matter input showed more desirable aggregate strength and soil fragmentation features, while systems with lower organic matter input showed increased cementation of dispersed clay with increased soil dryness, leading to higher aggregate tensile strength (Munkholm 2002, Munkholm *et al*. 2002). All these effects, however, were highly dependent on soil water content (Munkholm and Kay 2002).

In the Netherlands, Kouwenhoven *et al*. (2002) tested an 'ecoplough', developed to meet organic system requirements of relatively shallow ploughing with good soil inversion for weed control, on Luvisols. This plough has seven or eight bottoms for ploughing depths of 0.12–0.20 m, a working width of 2.1 m and a working speed of 1.7 m s^{-1}, and can be coupled with a tractor equipped with low-pressure tyres. The 'ecoplough' produced a rather smooth soil surface with relatively fine, strong, stable and moist aggregates. Organic matter, soil biota and nutrients were concentrated higher in the soil profile, which positively influenced soil workability and crop growth. Crop yields were similar to those after conventional ploughing, but weed populations (especially perennials) increased when ploughing depth was <0.2 m.

Most of these findings demonstrate that the abstraction of the tillage effect out of a cropping system context can lead to misleading conclusions. Furthermore, this 'reductionist' approach is highly questionable in organic farming, where agricultural management should always be systems based (Ikerd 1993). In general, it would always be desirable to first plan an organic crop rotation well suited to the local context and subsequently to tailor tillage choice and management to such a rotation (Wijnands 1999). Where some reduction in tillage frequency is desirable, inclusion of a no-till ley phase in the rotation should be considered (Olesen *et al*. 1999).

The relative importance of the pros and cons of tillage in a given environment should always be carefully considered before planning the crop rotation, based on the expected value of relevant soil and cropping system quality indicators (Table 1).

Are there any differences between tillage management in organic and conventional agriculture?

A logical assertion that could stem from what has been reported in the previous paragraphs is that hardly any differences can be seen between the theoretical approach to tillage management in conventional and organic agriculture. This is true if it is assumed that agroecosystem management, including tillage, should always be based on good agronomic practices regardless of the production system. In practice, however, there are some differences that are more related to cropping system structure and effect rather than to tillage itself. In a given context, organic cropping systems are invariably more diversified than their conventional counterparts (Stolze *et al.* 2000). The inclusion of more crops (including cover crops) in a rotation usually results in consequent diversification of tillage practices, either because requirements (e.g. for soil penetration resistance) may differ depending on type of cash crop and useful product (e.g. grain v. root crops) and/or because cover crops may need some degree of incorporation in soil to exert their positive agroecosystem functions (e.g. nutrient release).

In addition, organic systems usually enhance soil physical and biological fertility in the long term compared to conventional systems, such as aggregate stability, soil A horizon depth, organic matter content, porosity, earthworm abundance and activity, microbial biomass carbon (C) and N and their ratios to the total and light fraction C and N pools in soil, lower N microbial turnover rate and soil colonisation by mycorrhizae (Gerhardt 1997; Siegrist *et al.* 1998, Fließbach and Mäder 2000, Mäder *et al.* 2000, Pulleman *et al.* 2000, Friedel *et al.* 2001). These effects, which cannot easily be attributed to one or more specific agroecosystem components (including tillage) but rather to their positive interactions, by being beneficial to agroecosystem production, stability and resilience, can also bring about a new vision of tillage management. In a more stable and resilient agroecosystem it can be assumed that the potential disrupting effect of any disturbances, including tillage, would be buffered. Therefore, the degree of detail that should be paid to tillage management in an organic system is negatively correlated to the degree of stability and resilience of the system itself.

Skilled organic farmers know well that they have to integrate tillage management into their cropping system management strategy. Surprisingly, this integration is less obvious when examining the organic research literature, although there are exceptions. One of them is the so-called 'punch planting' method, also developed in Denmark. With this method, a hole is punched in the soil and a seed is dropped into it, without any seedbed preparation and soil disturbance outside the hole (Rasmussen 2003). Although this system has been developed mainly to improve in-row weed control (coupled with stale-seedbed and flame weeding) in row crops (e.g. fodder beet), it has also proved beneficial to soil tilth preservation. Conversely, Drinkwater *et al.* (2000) observed that compared to no-till management, post-emergence cultivation for direct weed control in maize also increased mineralisation of vetch residues, thus increasing N supply during maximum N demand by the crop.

Conclusions and future perspectives

It is not possible to generalise the effects of tillage management, since the positive or negative features depend largely on the agrienvironmental context and on cropping system structure. This is even more so in organic agriculture, where cropping system management cannot (and must not) be standardised, unlike what is usually done in conventional systems. It would be desirable to see more scientific projects and publications about not only the development of innovative, non-inversion tillage systems, but also with their actual integration in organic cropping systems planning and management. There is a discrepancy between the overall agreement on the need to apply system theory to organic farming and how mainstream organic farming research is usually conducted (Lockeretz 2000). Obviously, the requirements set forth by scientific communities as well as shortages in long-term research funding prevent many scientists from adopting a real system approach to organic farming research. However, this approach would be the most correct in organic systems (Niggli 1997); the hope is then to see it more frequently applied in future scientific papers.

References

Adams, W.A. and Jan, M.T. 1999. Utilization of nitrogen accumulated by a clover containing ley following cultivation. *Soil Use and Management* 15: 247–253.

Albrecht, H. and Matthei, A. 1998. The effects of organic and integrated farming on rare arable weeds on the Forschungsverbund Agrarokosysteme Munchen (FAM) research station in southern Bavaria. *Biological Conservation* 86: 347–356.

Asdal, Å. and Bakken, A.K. 1999. Nutrient balances and yields during conversion to organic farming in two crop rotation systems. In: Olesen, J.E., Eltun, R., Gooding, M.J., Steen Jensen, E. and Köpke, U. (eds) *Proceedings of the Workshop 'Designing and Testing Crop Rotations for Organic Farming'*. Borris, Denmark. DARCOF, Foulum. pp. 125–132.

Bàrberi, P. 2002. Weed management in organic agriculture: are we addressing the right issues? *Weed Research* 42: 176–193.

Bàrberi, P. and Lo Cascio, B. 2001. Long-term tillage and crop rotation effects on weed seedbank size and composition. *Weed Research* 41: 325–340.

Belde, M., Mattheis, A., Sprenger, B. and Albrecht, H. 2000. Long–term development of yield affecting weeds after the change from conventional to integrated and organic farming. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz* Special Issue S7: 291–301.

Drinkwater, L.E., Janke, R.R. and Rossoni–Longnecker, L. 2000. Effects of tillage intensity on nitrogen dynamics and productivity in legume-based grain systems. *Plant and Soil* 227: 99–113.

Eriksen, J., Askegaard, M. and Kristensen, K. 2004. Nitrate leaching from an organic dairy crop rotation: the effects of manure type, nitrogen input and improved crop rotation. *Soil Use and Management* 20: 48–54.

Eyhorn, F., Heeb, M. and Weidmann, G. 2002. *IFOAM Training Manual for Organic Agriculture in the Tropics*. FiBL, Frick.

Fließbach, A. and Mäder, P. 2000. Microbial biomass and size-density fractions differ between soils of organic and conventional agricultural systems. *Soil Biology and Biochemistry* 32: 757–768.

Friedel, J.K., Gabel, D. and Stahr, K. 2001. Nitrogen pools and turnover in arable soils under different durations of organic farming: II: Source–and–sink function of the soil microbial biomass or competition with growing plants? *Journal of Plant Nutrition and Soil Science–Zeitschrift für Pflanzenernahrung und Bodenkunde* 164: 421–429.

Gerhardt, R.A. 1997. A comparative analysis of the effects of organic and conventional farming systems on soil structure. *Biological Agriculture and Horticulture* 14: 139–157.

Gruber, H., Handel, K. and Broschewitz, B. 2000. Influence of farming system on weeds in thresh crops of a six-year crop rotation. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz*. Special Issue S7: 33–40.

Henriksen, C.B., Søgård, C. and Rasmussen, J. 2000. Kemink subsoiling may stimulate the growth of sugar beets. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *Proceedings 13th International IFOAM Scientific Conference*. ETH, Zurich. p. 407.

Hidaka, K. 1997. Community structure and regulatory mechanism of pest populations in rice paddies cultivated under intensive, traditionally organic and lower input organic farming in Japan. *Biological Agriculture and Horticulture* 15: 35–49.

IFOAM 2005. *Draft Standards*. International Federation of Organic Agriculture Movements, Bonn. <http://www.ifoam.org/about_ifoam/standards/norms/draft_standards/draft_standards.html>. Accessed 18/1/06.

Ikerd, J.E. 1993. The need for a system approach to sustainable agriculture. *Agriculture Ecosystems and Environment* 46: 147–160.

Kouwenhoven, J.K., Perdok, U.D., Boer, J. and Oomen, G.J.M. 2002. Soil management by shallow mouldboard ploughing in The Netherlands. *Soil and Tillage Research* 65: 125–139.

Liebman, M. and Davis, A.S. 2000. Integration of soil, crop, and weed management in low-external-input farming systems. *Weed Research* 40: 27–47.

Lockeretz, W. 2000. Organic farming research, today and tomorrow. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *Proceedings 13th International IFOAM Scientific Conference*. ETH, Zurich. pp. 718–720.

Mäder, P., Edenhofer, S., Boller, T., Wiemken, A. and Niggli, U. 2000. Arbuscular mycorrhizae in a long-term field trial comparing low-input (organic, biological) and high-input (conventional) farming systems in a crop rotation. *Biology and Fertility of Soils* 31: 150–156.

Mando, A., Ouattara, B., Sédogo, M., Stroosnijder, L., Ouattara, K., Brussaard, L. and Vanlauwe, B. 2005. Long-term effect of tillage and manure application on soil organic fractions and crop performance under Sudano–Sahelian conditions. *Soil and Tillage Research* 80: 95–101.

McCloskey, M., Firbank, L.G., Watkinson, A.R. and Webb, D.J. 1996. The dynamics of experimental arable weed communities under different management practices. *Journal of Vegetation Science* 7: 799–808.

Munkholm, L.J. 2002. Soil fragmentation and friability. Effects of soil water and soil management. PhD thesis, Danish Institute of Agricultural Sciences, Foulum and The Royal Veterinary and Agricultural University, Copenhagen.

Munkholm, L.J. and Kay, B.D. 2002. Effect of water regime on aggregate tensile strength, rupture energy and friability. *Soil Science Society of America Journal* 66: 702–709.

Munkholm, L.J., Schjønning, P. and Kay, B.D. 2002. Tensile strength of soil cores in relation to aggregate strength, soil fragmentation and pore characteristics. *Soil and Tillage Research* 64: 125–135.

Munkholm, L.J., Schjønning, P. and Petersen, C.T. 2001a. Soil mechanical behaviour of sandy loams in a temperate climate: case studies on long-term effects of fertilization and crop rotation. *Soil Use and Management* 17: 269–277.

Munkholm, L.J., Schjønning, P. and Rasmussen, K.J. 2001b. Non-inversion tillage effects on soil mechanical properties of a humid sandy loam. *Soil and Tillage Research* 62: 1–14.

Niggli, U. 1997. Organic agriculture research: state of the arts and future priorities and comments on the report of Els Wynen. In: Krell, R. (ed.) *Biological Farming Research in Europe. Proceedings of an Expert Roundtable, Braunschweig, Germany*. FAO, Rome. pp. 54–55.

Olesen, J.E., Rasmussen, I.A., Askegaard, M. and Kristensen, K. 1999. Design of the Danish crop rotation experiment. In: Olesen, J.E., Eltun, R., Gooding, M.J., Steen Jensen, E. and Köpke, U. (eds) *Proceedings of the Workshop 'Designing and Testing Crop Rotations for Organic Farming'. Borris, Denmark*. DARCOF, Foulum. pp. 49–62.

Petersen, H. 2002. Effects of non–inverting deep tillage vs. conventional ploughing on collembolan populations in an organic wheat field. *European Journal of Soil Biology* 38: 177–180.

Pulleman, M., Bouma, J., van Essen, E.A. and Meijles, E.W. (2000). Soil organic matter content as a function of different land use history. *Soil Science Society of America Journal* 64: 689–693.

Pulleman, M., Jongmans A., Marinissen, J. and Bouma, J. (2003). Effects of organic versus conventional arable farming on soil structure and organic matter dynamics in a marine loam in the Netherlands. *Soil Use and Management* 19: 157–165.

Rasmussen, I.A., Askegaard, M. and Olesen, J.E. (1999). Weed control in organic crop rotations for grain production. In: Gut, D. (ed.) *Proceedings 11th EWRS Symposium*. Basel, Switzerland. European Weed Research Society (EWRS), Wageningen. p. 98.

Rasmussen, J. 2003. Punch planting, flame weeding and stale seedbed for weed control in row crops. *Weed Research* 43: 393–403.

Schmidt, H., Philipps, L., Welsh, J.P. and von Fragstein, P. 1999. Legume breaks in stockless organic farming rotations: nitrogen accumulation and influence on the following crops. *Biological Agriculture and Horticulture* 17: 159–170.

Siegrist, S., Schaub, D., Pfiffner, L. and Mäder, P. 1998. Does organic agriculture reduce soil erodibility? The results of a long-term field study on loess in Switzerland. *Agriculture, Ecosystems and Environment* 69: 253–264.

Stolze, M., Piorr, A., Häring, A. and Dabbert, S. (eds) 2000. *The Environmental impacts of Organic Farming in Europe*. University of Hohenheim Press, Hohenheim.

Stopes, C., Millington, S. and Woodward, L. 1996. Dry matter and nitrogen accumulation by three leguminous green manure species and the yield of a following wheat crop in an organic production system. *Agriculture, Ecosystems and Environment* 57: 189–196.

van Bruggen, A.H.C. and Termorshuizen, A.J. 2003. Integrated approaches to root disease management in organic farming systems. *Australasian Plant Pathology* 32: 141–156.

van der Weerden, T.J., Sherlock, R.R., Williams, P.H. and Cameron, K.C. 2000. Effect of three contrasting onion (*Allium cepa* L.) production systems on nitrous oxide emissions from soil. *Biology and Fertility of Soils* 31: 334–342.

Wijnands, F.G. 1999. Crop rotations in organic farming: theory and practice. In: Olesen, J.E., Eltun, R., Gooding, M.J., Steen Jensen, E. and Köpke, U. (eds) *Proceedings of the Workshop 'Designing and Testing Crop Rotations for Organic Farming'*. Borris, Denmark. DARCOF, Foulum. pp. 21–35.

Zanin, G., Otto, S., Riello, L. and Borin, M. 1997. Ecological interpretation of weed flora dynamics under different tillage systems. *Agriculture Ecosystems and Environment* 66: 177–188.

Chapter 13

Food quality

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Abstract

In response to the greatly increased market share of organic food, there is an increasing interest in investigating whether there is any difference in the effects of organic and conventional food on health. Previous studies have not been able to provide definitive proof for differences between these two food production systems in terms of human health. This conclusion mainly suggest that the designs of these studies were neither adequate to provide such proof, nor targeted to those aspects where differences are most likely.

However, there are ample examples that the methods used for food production do make a difference to food composition or other aspects of its quality, and that these differences are large enough to make a real difference for the consumer in terms of health. While these differences may cause yet unproven general differences in food quality between organic and conventional products, many of the methods that benefit food quality are not necessarily restricted to either organic or conventional systems. Understanding the links between production methods and food quality, therefore, allows improvement of the products of any system, whether organic or conventional. However, some of these benefits are linked with what is common practice in organic farming, and for these the main challenge can be to conserve existing quality benefits during further development of the productivity of organic methods.

Introduction

Relationships between organic regulations and food quality

Organic food production is defined by the International Federation of Organic Agriculture Movements (IFOAM) as a set of principles that should be fulfilled as much as possible, and by the European Union (EU), and other international, national or private bodies and certifiers as a legally binding certification standard, defining what is allowed and required in order to qualify for this label (see *Chapter 9*). Although the IFOAM principles do mention quality as a desired aim, none of the specified requirements actually refer to quality or safety, beyond general requirements that need to be observed by all food producers. In a stringent sense, the quality of organic food is thus a process quality rather than a product quality. For the primary production steps in the supply chain, systematic effects on food quality are mainly, or only, indirect, results of the specified farming methods. For example, banning synthetic fertiliser and pesticides means that the nutrient supply to the crops needs to be provided from sources with a relatively slow release of plant nutrients. The lower levels of available N affects the plant physiology so that there are relatively high concentrations of ascorbic acid (vitamin C) in the plant tissues, including harvested vegetables (Mozafar 1993). But the effect is indirect, because the regulation only specifies which inputs are banned, it does not specify the level of vitamin C in the product, and the quality advantage can be lost without violating the regulation (e.g. if the variety used by the organic farmer is one with a low capacity for forming vitamin C) (Justesen *et al*. 1998). For processed foods, a few regulations directly influence specific aspects of quality by banning of synthetic colourants, artificial flavouring agents and antimicrobial additives. Still, there are no requirements for positive taste or health effect qualities, only for the absence of these additives, which are considered negative by many consumers even though actual health risks for those additives that are allowed in conventional foods have not been proven (Brandt and Mølgaard 2001). However, while the support from governments and official agencies only refers to environmental benefits, many consumers are convinced that organic foods taste better than conventional products and cite possible beneficial effects on health as a major reason for buying organic foods (Schifferstein and Ophuis 1998, O'Doherty Jensen *et al*. 2001). In response to the greatly increased market share of organic food, there is an increasing interest in investigating whether there are any differences in the effects of organic and conventional food on health.

Reviews of earlier studies of organic food and health

Numerous studies have compared food produced according to the organic standards with conventionally produced food in attempts to elucidate whether different farming methods result in different effects on human health. Several ministries and other organisations have organised reviews of these studies; for example, those by Woese *et al*. (1997), O'Doherty Jensen *et al*. (2001), Bourn and Prescott (2002), Food Standards Agency (2002), Soil Association (2002), Williams (2002), AFSSA (2003), BMVEL (2003), Kouba (2003), Lotter (2003) and Magkos *et al*. (2003).

The reviews concluded that there is no evidence for any direct health benefits nor risks definitively associated with the consumption of organic foods. Significant differences exist in the average levels of several nutrients, contaminants or pathogens regarding food composition, however. Most, but not all, of these differences appear to be beneficial on the part of the organic food and organic foods tend to contain substantially lower levels of pesticide residues and slightly higher vitamin C content, but there is no evidence that differences of the measured magnitudes are so great as to have any effect on health. One of the reviews carried out by the Soil Association (Soil Association 2002) chose to conclude therefore that while not definitive, the evidence was in favour of a benefit of unknown magnitude from eating organic food. Other reviews conducted by various agencies or expert groups financed by a government preferred the more conservative interpretation of the same body of data in accordance with the convention normally used in science, that the available evidence does not allow rejection of the null hypothesis of no effect. However, most of the reviews specifically pointed out that the absence of evidence is due to absence of relevant data. There are no well-designed experimental studies showing definitively that there is no difference. The studies included in the reviews were not designed to be able to provide definitive evidence for differences between these two food production systems in terms of effect on human health, and/or were not targeted to those aspects where differences are most likely.

Due to this, the state of the art in terms of scientific consensus is that no well-defined problem of direct toxicity, pathogenicity or nutrient deficiency, nor any benefit with a well-defined impact on health, has been proven to be specifically associated with either organic or conventional food. To place this in perspective, a similar statement can be made regarding the

Atkins diet relative to other diets with comparable caloric intake, which represent much larger differences in composition.

Previous studies have not been able to provide definitive evidence for differences between these two food production systems in terms of effect on human health; and this conclusion suggests that the designs of these studies were possibly inadequate to provide such evidence, and/or were not targeted to those aspects where differences are most likely.

However, there are ample examples that the methods used for food production do make a difference for food composition or other quality aspects, and that these differences are large enough to make a difference to consumer health. Although these differences may cause (yet unproven) general differences in food quality between organic and conventional products, many of the methods that benefit food quality are not necessarily restricted to either organic or conventional systems. Understanding the links between production methods and food quality therefore allows improvement of the products of any system, whether organic or conventional. However, some of these benefits are linked with what is common practice in organic farming, and for these the main challenge can be to conserve existing quality benefits during further development of the productivity of organic methods.

Definitions of production systems and food qualities

Differences between production systems that may affect food quality

Organic food production is founded on some basic principles, regulated by a set of rules and laws and is as such, relatively well defined. Conventional production operates within a larger area of production conditions. One fundamental set of production parameters is the combination of nutrient and foreign compound inputs. Plant production can tentatively be described as a function of plant nutrient inputs (primarily nitrogen) and foreign compounds (pesticides) (Figure 13.1). Likewise, animal production can be described on the basis of inputs of feed (kJ) and foreign compounds (antibiotics, hormones, growth promoters) (Figure 13.2). As the two figures show, the production systems are not totally separated, although the average production conditions are different. This is important when comparing organic versus conventional food, because one can end up comparing two food items produced under literally identical conditions. If this is the case, it is unlikely that the products are significantly different. However, quality or health effects that systematically result from those factors that separate the systems the most, will also result in a difference in product quality between the systems and consequent health impacts, even if the food producers are not consciously trying to obtain this quality and even when some products from each system will have overlapping properties. The influence of cultivar and soil type is also important when comparing plant products, as well as the influence of breed and housing system when comparing animal products. For both climate and local national and regional conditions, traditions and preferences also have a profound effect on a range of quality aspects. In particular, the production systems that tend to use different cultivars/breeds or procure raw materials produced in different locations have to be taken into account in a comparison, if the purpose is to determine the effect on consumer health, and/or satisfaction with sensory qualities of the food.

Strategies to measure the effects of production methods on food quality

It is very difficult to make an overall comparison of the organic and conventional production systems as a result of the high variability and there is not much purpose in trying. Even if it were possible to somehow assess the quality of enough volumes of organic and conventional foods to provide precise figures for all significant differences between these two systems, this

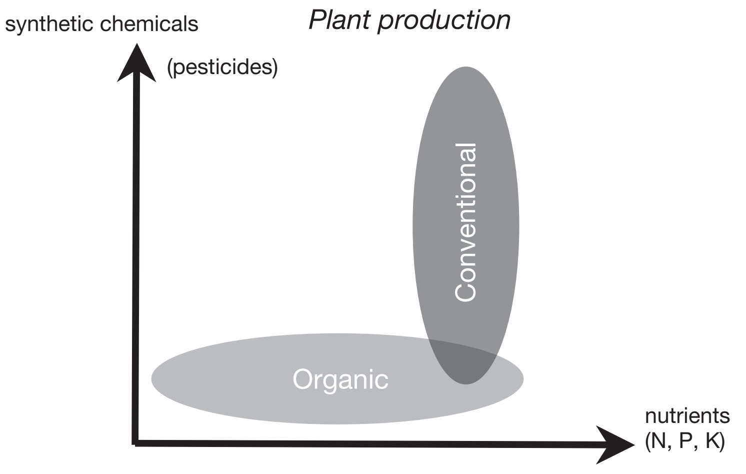

Figure 13.1 Relationship between nutrient inputs and the use of synthetic compounds in organic and conventional plant production.

would just show the situation at the time of the study. Once the data had been compiled and were ready to publish, new varieties may have been introduced, or farming practices or trading patterns may have changed in either system, and the comparison would no longer be valid.

In contrast, it is both feasible and relevant to investigate the effects of specified aspects of organic and conventional farming systems on food quality, including effects on human health. Variation can be reduced by keeping constant those factors that are not being investigated. The investigation is relevant because if we come to better understand whether and how choices made by farmers, processors, traders and others involved in food supply chains affects health, this will allow systems improvement, not just documentation of a snapshot of a constantly changing situation. Knowing these causes and effects can also be used to ensure that better systems are developed for increased productivity and other desirable aspects, without losing existing advantages of quality, by estimating the effect of a change in the causal factors before it is implemented.

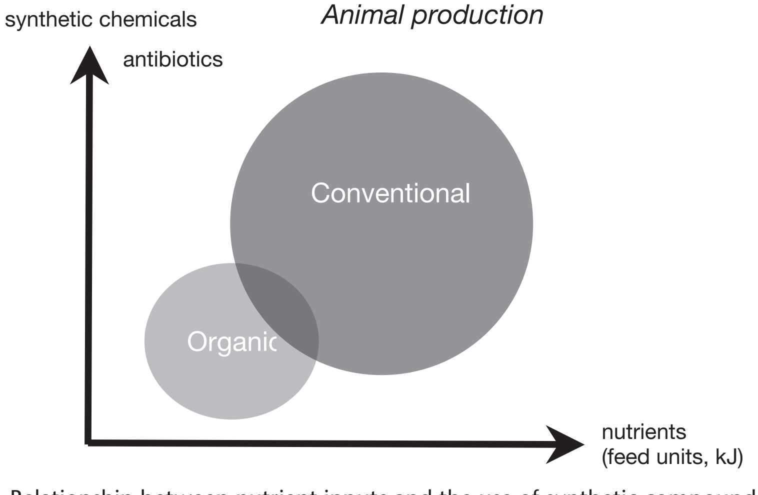

Figure 13.2 Relationship between nutrient inputs and the use of synthetic compounds in organic and conventional animal production.

Such studies should be very precise. Products should preferably be grown or raised on experimental farms where production conditions can be controlled (Harker 2004), particularly when several combinations or options within a production system are tested. Another useful approach is the paired comparison of similar, neighbouring farms producing the same cultivar or breed under the two different production regimes. Studies need to include some assessment of the product to be consumed, including (if relevant) the preparation taking place in the home.

Surveys can still be useful since they integrate the outcome of all the factors along the entire supply chain to test predictions and assess whether models are taking the relevant factors into account, as well as generating new hypotheses when this is not the case. However, if done as isolated studies, the results of food quality surveys obtained at the point of sale have very little predictive power, unless extensive additional data are collected (e.g. origin, variety/breed, storage extent, conditions). Often this is not possible.

Finally, when assessing results of previous studies in this area, the important rapid development in organic production systems in recent years needs to be taken into account. For example, between 1993 and 2000 the number of organic holdings in the EU increased from 29,000 to 130,000 (European Union 2001). Two general consequences of this expansion are likely to have had profound implications for food quality, although neither can be measured directly. First, the organic producers have become increasingly professionalised and specialised in response to the demand for large volumes of uniform products for the supermarkets, Two to 15 years ago, depending on country, a substantial proportion of the marketed organic food did not correspond to the conventional trade standards in terms of, for example, size and blemishes, whereas today, most organic food superficially resembles conventional products. Whether this is a quality improvement or not is debatable, but it means that results from survey studies made before this transition are unlikely to be relevant today.

Another aspect of rapid change is that most organic producers and others involved in organic supply chains have only been working with organic food for a few years. While organic production, until recently, mainly took place in close-knit communities where newcomers received extensive training and based their work on the accumulated experience of the community, the sheer volume of new producers has made such transfer of knowledge much more difficult. Many producers base their work primarily on concepts learned in conventional production with some adjustments to accommodate the requirements for organic certification. Of course, these new producers eventually obtain experience through their own successes and failures, but in the meantime, the quality of the food very likely deviates from what is typical for experienced organic producers. This consequence of the expansion will almost inevitably persist until the availability and quality of advisers catches up with expansion, and influences the change in organic food quality over time in a pattern specific to each region and for each commodity produced. A particular concern is that scientists studying organic food quality also have very variable levels of expertise on the practical aspects of organic farming. Close inspection of scientifically and well-designed investigations pertaining to organic food quality often reveals that although the 'organic production' treatments normally conform to relevant certification requirements, they often do not correspond to the practice of experienced organic producers in the relevant region (e.g. as indicated by yield figures). This also affects the relevance of the results of such studies, from extrapolation to assessments of the food available for consumers.

Aspects of food quality

Food quality is not a single property that can be measured by an easily defined and agreed method. The overall definition of food quality is a collection of food properties that satisfy or exceed the expectations of the consumer. This comprises a very broad range of properties, including for example, fair trade relations and short transport distances (Torjusen *et al*. 2004). This is exemplified in the way that organic food quality comprises a range of quality benefits: authentic, functional, biological, nutritional, sensual and ethical benefits (Meier-Ploeger 1996). However, the scientific literature does not contain generally agreed methods to measure the effect of food on the full range of benefits. However, a range of new methods are under development, which could be able to provide such measurements (Meier-Ploeger *et al*. 2004) if they can be shown to consistently correlate with other measures of these properties. Since this has not yet been achieved, the present text will only attempt to cover studies on quality in relation to consumer health, as defined by measures that are generally accepted in the scientific community, comprising many of the functional, biological and nutritional benefits of good food quality. Some sensory properties are mentioned when they relate to health. This chapter does not include a comprehensive review of the influence of production methods on the taste and aroma of food, since little information is available and it is difficult to make any meaningful conclusions beyond specific examples.

Concerning health, a typical rationale among consumers is that healthy soils, plants and animals are the basis for human health, and therefore that care and concern for any of these environmental factors will also promote better human health (Torjusen *et al*. 2004). Since the health of soils, plants and animals, as well as environmental effects are described elsewhere in this book, this chapter concentrates on the few aspects of food-related health that are directly related to the chemical, microbiological and physical properties of the food:

- safety from pathogens;
- safety from toxic substances; and
- beneficial nutritional properties or other positive impacts on health.

However, although these aspects are discussed as separate topics below, in line with the way scientific studies and regulatory issues are normally defined, most consumers still see them as parts of a holistic picture where the good intentions of the people involved in the food supply chain are the most important assurance for all aspects of food quality. In this context, stringent safety measures and sophisticated process control, which are the cornerstone of food quality assurance schemes in conventional supply chains, may be seen by consumers at best as self-imposed restrictions that prove the sincerity of these good intentions, and at worst as unfair, unnecessary burdens introduced through lobbying from big profit business to support its suppression of small-scale or local producers.

Safety from pathogens

In conventional agriculture, food safety assurance systems to prevent transmission of pathogens by food are often based on the idea that all pathogen contamination should be prevented through stringent isolation procedures, and if contamination occurs, the whole system should be thoroughly decontaminated before production can be re-established. From this viewpoint, the demand for access to outdoor areas for farm animals and the use of animal manure for crop production represent almost unethical violations of best practice. Some authorities have reacted by imposing what can appear as rather draconian requirements, such as heat treatment of animal wastes before they can be used on crops. For example, the National Organic Program (2000) regulations in the United States of America (USA) require:

> that compost must be produced through a process that combines plant and animal materials with an initial C:N ratio of between 25:1 and 40:1. Furthermore, producers using an in-vessel or static aerated pile system must maintain the

> composting materials at a temperature of between 131°F (55°C) and 170°F (77°C) for 3 days. Producers using a windrow system must maintain the composting materials at a temperature between 131°F (55°C) and 170°F (77°C) for 15 days, during which time, the materials must be turned a minimum of five times.

Organic farmers tend to think that their production methods keep the animals and soils so healthy that any zoonotic pathogens introduced from other farms or wild animals are quickly eliminated through natural protection mechanisms. Surveys and comparisons reviewed by Korba (2003), BMVEL (2003) and Bourn and Prescott (2003) concluded that the microbiological risk from organic foods is smaller or similar to corresponding conventional foods, even though pathogens are able to survive for extended periods in stored manure. The information tends to be based on surprisingly few studies often of rather low information value. For example, a report is cited in Korba *et al.* (2003) to 'show that, compared to conventional agriculture, organic production leads to a higher *Salmonella* contamination in eggs, poultry meat and pork meat'. In the report, which was not peer-reviewed (European Union 2001), this conclusion refers to the statement 'in comparison with conventional farming, more cases of salmonella in eggs, poultry and pig meat have been registered', without any figures, author identification or other information that allows tracking of the source in order to define the year and geographical area to which it referred. A recent initiative by a Dutch research group aims to understand and control the factors that determine the pathogen transmission risk in the entire organic vegetable production chain, from the feeding regime of the cows to the post-harvest treatment of the vegetables (Franz *et al.* 2003).

A few studies hint at some of the reasons for the absence of predicted risks, and indicate that organic food may be safer than estimated. Hald *et al.* (1999) suggested that if organic farm animals tend to be exposed to zoonotic pathogens like *Salmonella* at an early age and then become so resistant that the infections are eliminated before slaughter, the pathogen load will be systematically overestimated if testing is done by measuring antibodies in the animal tissues rather than actual presence of the pathogen in faeces. An ongoing study in the EU-project QualityLowInputFood (QLIF 2006), is testing this hypothesis by comparing antibodies in meat samples and bacteria in faeces in organic and conventional pigs from defined outdoor and indoor farming systems (M.K. Bonde pers. comm.). Some studies indicate that the more extensive use of grass and other roughage in organic animal production improves the ability of the animals to eliminate zoonotic pathogens (Couzin 1998, Diez-Gonzalez *et al.* 1998). Another aspect of the issue of zoonotic pathogens in organic animals is that out of necessity, organic farmers have to give high preference to good health characteristics when selecting breeding stock, since it is more difficult or impossible to control health problems by antibiotics. In the USA, where a total ban on the use of antibiotics for organic cattle has forced milk farmers to select heavily for highly resistant stock, some organic farmers have now started selling their surplus heifers to conventional farmers at a premium price, since even in a conventional system, genetic resistance is more effective than antibiotic treatment in keeping animals healthy (J. Riddle pers. comm., 2005). Although no studies on the impact of animal genetic resistance on food safety have been reported, this is an aspect that should be investigated in future research. It is also an example of how organic production system developments can directly benefit conventional producers.

Regarding pathogen transfer from manure to vegetables, several studies have failed to show measurable contamination of the final product when *Salmonella* or *Escherichia coli* O157:H7 were deliberately introduced into lettuce growing systems (Johannessen *et al.* 2004, U. Köpke pers. comm., 2005). Studies in the Netherlands (Franz *et al.* 2005) highlight two important components of this elimination: first, the numbers of pathogens (added by inoculation) fell faster during storage at 15°C in manure from cows, the more grass and less concentrate was used in the their diet (three different treatments); second, when mixed with (a conventional) soil, pathogen numbers were quickly reduced in all treatments except in sterilised soil, and pathogen numbers fell faster when the soil was mixed with organic manure than when the same amount of conventional manure was added.

Whereas neither of these studies definitively rules out that pathogens can enter the organic food chain through animal or plant products, they support the observations made by organic farmers of relatively good resilience to infections. Together, this shows an imminent need for well-designed studies to determine the efficacy of various procedures and their combinations as used in organic farming to eliminate pathogens introduced at various levels of the food chain. If the concept of suppressive soils can control not only plant pathogens (see *Chapter 4*), but also zoonotic pathogens, the concept of a healthy soil will gain a completely new angle. However, this effect may depend on special conditions that may not be present on all organic farms, and it is therefore very important to understand the process in greater depth before it can be used as an effective safety provision.

One study (Tschape *et al.* 1995) reported a foodborne infection by the verotoxinogenic bacterium *Citrobacter freundii* in a nursery school in Germany caused by contaminated parsley from an organic garden in which manure of pig origin was used. The bacterium produced symptoms of gastroenteritis and Haemolytic Uremic Syndrome (HUS) in about 15 people, one dying of HUS (Lund 2002). This seems to be the most recent case recorded, and predates the establishment of defined standards and regular certification visits for organic farming. Although most organic certification schemes are not meant to regulate general good practice in terms of food safety, inspectors observing violations of general safety guidelines should still advise producers to meet those standards as well as the special requirements for organic certification.

Additionally several surveys show that the restricted use of antibiotics in organic agriculture reduces the problems of antibiotic resistance, a theme that is very important in relation to zoonotic pathogens. These studies demonstrate that isolates of relevant bacteria from organic dairy herds were significantly more susceptible to antimicrobials than those from conventional herds in the USA, Denmark and Scotland (Tikofsky *et al.* 2003, Sato *et al.* 2004, Hoyle *et al.* 2004).

Another disease, bovine spongiform encephalopathy (BSE, ‘mad cow disease’), arises when animals are fed contaminated tissues from other animals with the disease. Organic regulations have never allowed the use of animal residues as feed for animals of the same species, and although at least one cow raised in a conventional herd that was later converted into organic did develop BSE, until now BSE has not been detected in any cattle born in organic herds (Kouba 2003, BMVEL 2003). Technically these data represent a significantly lower statistical risk from organic than from conventional meat, but since the overall risk is very small this difference does not have any measurable effect on consumer health.

Overall, while organic production methods may superficially appear to comprise more risks for pathogen transmission from farm animals to humans than conventional farms, the evidence indicates the opposite trend, although not complete safety. And if bad luck strikes, pathogens from organic animals are more susceptible to antibiotics and are thus easier to eliminate from patients.

Safety from toxic substances

Synthetic toxins intentionally applied to the food

Many consumers are concerned about the use of synthetic pesticides, food additives and veterinary medicines, which they perceive as possible health risks (O’Doherty Jensen *et al.* 2001).

Consumers find this risk unacceptable, since the presence of organic products show that these production aids are unnecessary (Torjusen *et al* 2004), so they are seen as indicators that the conventional producers are more concerned with profits than with food quality. The authorities consistently find detectable synthetic pesticide residues in a substantial proportion of samples analysed from conventional farms. Some samples contain more than one residue. Few conventional samples exceed tolerances and most residues are well below tolerance levels. Residues are commonly not present on organic produce and, where present, residue levels are significantly lower in organic products than in corresponding conventional ones (Weber *et al.* 2001, Baker *et al.* 2002). However, all pesticides, food additives and so forth used by conventional food producers are thoroughly tested to determine whether they pose any health risk. If such indications are found, they are prohibited, so the occurrence of residues in present day conventional food is not considered a significant health risk (Diehl 2002). However, history has taught us that chemicals considered harmless today might be labelled ‘poisonous’ in the future, and little is known about how combinations of low levels of pesticides affect human health. For example, a study on the effect of the growth regulator chlorocholine chloride indicated significant reductions in semen quality among rats fed wheat grown with this substance, compared with untreated wheat (Torner *et al.* 1999). This study is being followed up with a study on pigs in the QLIF project (M.T. Sørensen, pers. comm., 2005).

In addition, preservative substances and food colourings used in conventional food have been implicated as health risks (Dengate and Ruben 2002, Bateman *et al.* 2004), but here also, the effects are difficult to measure, and there is no consensus in the scientific community on safe levels. The recent increased acceptance of the concept of hormesis (i.e. that effects at low concentrations can be opposite, normally beneficial, than the normally toxic effects at high doses) is likely to lead to a complete re-evaluation of the existing framework for safety evaluation (Calabrese 2004), but the outcome of hormesis is impossible to predict. Some authors argue that hormesis means that all synthetic pesticides are generally much safer than previously thought (Trewavas 2004). On the contrary, others caution that when the possibility of hormesis is ignored, poorly devised dose-response curves could lead to either underestimating or overestimating the risk at the actual exposure levels (Calabrese 2004).

So although there is no doubt that the presence of pesticide residues and food additives is significantly different between organic and conventional foods, there are no generally accepted volumes of data showing that the difference in composition makes a difference to the health of consumers. However, a more precise estimate of the magnitude of risk from pesticide residues or food additives may not make much difference to the view of many consumers, who do not want to take any risk, no matter how small, when not associated with clear benefits for themselves (Torjusen *et al.* 2004).

There may be some effect on consumer views if clear health benefits are proven. However, ensuring a defined level of residues in food will be even more difficult than keeping the levels below a certain limit. As described below (see *Indirect measurements of effects on health)*, if pesticide residues are good for health, organic foods will be better still because of their high content of natural pesticides.

Synthetic toxins unintentionally occurring in food (pollutants)

Although most pollutants would be considered equally likely to occur in organic and conventional foods, Harnly *et al.* (2000) found the level of dioxins was seven times higher in eggs from free-ranging private flocks with unlimited access to soil in a strongly polluted area in the USA than flocks kept in a confined soil area in the same region, and that the high levels contained in many eggs constituted a definitive human health danger. Since organic egg production must include access to outdoor runs, this finding caused great concern for organic egg producers. A recent Belgian study, while confirming high dioxin levels in eggs from small private flocks in a polluted area, found that the levels of dioxin contamination in eggs from seven organic farms were slightly (but not significantly) lower than samples from 10 conventional farms, and all within a level normally considered safe (Pussemier *et al.* 2004). Since then, one study showed elevated dioxin levels in eggs from two out of four organic farms in an Irish survey (Food Safety Authority of Ireland 2004). Here it was found that the age of the hens was also important for this pollutant, which is known to accumulate in the body. The flocks with the highest values comprised hens of up to four years of age, but the concentrations were still lower than eggs from polluted areas, and did not exceed the safety limits. In general, while additional experiments are required to test the hypotheses presented, if they are confirmed, two simple safety precautions should be able to control this problem for organic (and other free-range) egg producers: test for soil pollution before establishing chicken production, and limit the age of the hens to no more than two laying seasons. Conventional producers and most organic ones keep layers for only one laying season, but in accordance with organic principles, healthy animals should keep producing for longer periods if this does not conflict with animal welfare considerations. Dioxins do not accumulate in plants (Harnly *et al.* 2000), and cattle and pigs, which occupy more space than chickens, are less likely to be produced near large cities where polluted areas typically occur. New data indicate that low levels of dioxins may not be as dangerous as was previously estimated; a review by Calabrese and Blain (2005) states that 42 papers show beneficial health effects of low doses of dioxins (hormesis).

Similar considerations are relevant for other airborne, persistent, bioaccumulating pollutants, primarily polychlorinated biphenyl (PCB) and dichlorodiphenyltrichloroethane (DDT).

Naturally occurring toxins – mycotoxins

Mycotoxins are fungal metabolites produced in infected plant material following infection with various fungal species, such as aflatoxins from *Aspergillus* species and fumonisins produced by strains of *Fusarium*. Studies of samples taken from fields have shown either no difference in mycotoxin content (Hietaniemi *et al.* 2004) or lower content in the organic samples compared to the conventional ones (Schollenberger *et al.* 1999, Schollenberger *et al.* 2002, Birzele *et al.* 2002, Doll *et al.* 2002). Although most studies were surveys, the study by Bizele *et al.* (2002) included a controlled cultivation experiment where the infection rate was consistently highest in wheat grown with conventional mineral fertiliser and without pesticides, intermediate in conventionally grown wheat (mineral fertiliser, with pesticides) and lowest in organic wheat (organic fertilisation, no pesticides). The mycotoxin content in the grain was more variable, as the conventional and organic treatments were similar, with both still lower than the experimental combination of mineral fertiliser without pesticides. This study showed that under German climatic and soil conditions, the type of fertility management is more important for the extent of *Fusarium* infection than the use of pesticides. While this conclusion may be unexpected for conventionally trained scientists and advisers (e.g. Trewavas 2004), it is consistent with some other studies showing no or small differences in infection rates between organic and conventional crops (e.g. van Bruggen 1995). However, of note to the organic community is that although the relatively low and/or slow nutrient supply in organic farming helps to trigger the plants' natural defences against infections, it is achieved at the expense of some of the theoretical yield potential. This problem cannot be solved by improving the methods for acquisition, retention and release of nutrients – excessive use of organic fertilisers may lead to the same quality problems that haunt conventional cereal producers (e.g. Pedersen and Bertelsen 2002).

In the late 1990s, Danish studies found problems with the concentrations of mycotoxins in organic cereals. They were as a result of improper management, drying and storage facilities, related to easily alleviated deficiencies in the advice provided to farmers and not due to the farming system (Elmholt 2003). Nevertheless, this caused the average contamination in marketed foods to be higher in organic than in conventional products for a time (Jørgensen *et al.* 2000), again highlighting the need to understand the causes of the differences found in survey-type investigations.

In relation to food quality, cereals with low fungal infection levels are unsuitable for flour or muesli production for human consumption, due to a distinctive off-taste or inferior baking quality. Apart from certain nuts and pulses, the risk to the consumer is very low. Infected grains can still be used in moderate amounts for animal feed, and while mycotoxins can then occur at detectable levels in meat, eggs or milk, the animals will show clear signs of poisoning or even die before the levels become sufficiently high to pose a health risk to human consumers. However, routine surveillance for signs of mycotoxin poisoning ('white kidneys') at abattoirs, and for mycotoxin residues in milk and eggs, are still important as measures to detect and enforce violations of good practice in terms of animal welfare.

Apart from the question of how the farming system affects concentrations of mycotoxins, additional uncertainty exists in relation to the effects of different levels on human and animal health. The present safety regulations require that levels are a defined number of magnitudes lower than those resulting in harmful effects in animal studies; mainly liver damage or cancer. However, this method is very imprecise – safety limits set too low may lead to the destruction of large volumes of food or feed, whereas limits set too high expose consumers to significant health risks.

In a recent comparison of wheat samples produced in Italy, mycotoxin content was highest in organic samples, although still well below the level considered safe for consumption. However, *in vitro* lymphocyte cultures demonstrated that the immunotoxic effect of the conventional wheat was higher than that of the organic (Finamore *et al.* 2004). The authors suggested that this was as a result of toxic effects of pesticide residues or other unknown contaminants in the conventional wheat. However, since 22 mycotoxin studies are reported to demonstrate hormesis (beneficial effects at low exposure levels) (Calabrese and Blain 2005), the data could equally well indicate that consumption of food with low levels of mycotoxins may strengthen the immune system rather than harming it.

Naturally occurring toxins – plant toxins

Another class of naturally occurring toxins is the natural toxicants produced by plants as a defence against diseases and pests, including essential oils in myrtaceous plants and glucosinolates in Brassica species. From the perspective of the plant, humans are just another herbivore, and the chemical defences that protect it against animal herbivores affect humans just as effectively. Fortunately, modern humans have inherited the physiological mechanisms to cope with plant defences from our herbivorous primate ancestors that allow us to safely extract an optimal amount of nutrients from plant foods such as vegetables. The best known protective mechanism is our ability to degrade and/or excrete most naturally occurring plant chemicals (as well as many unnatural chemicals). There are no reported cases of long-term harmful effects on any humans of low to medium exposures to toxins from normal food plants, unless combined with malnutrition (since some plant toxicants exert their effect by inhibiting uptake or blocking utilisation of key nutrients). All other known cases of harm to humans were as a result of short-term intake of plant material with very high levels of toxicants.

A less known, but probably more important, protective mechanism is 'conditioned taste aversion' (Cross-Mellor *et al.* 2004), which induces a rapid, profound aversion to any taste associated with nausea or other indications of toxicosis. This study used an ingenious setup allowing continuous control of the induction of nausea to show that conditioned taste aversion is so precise that it allows rats to adjust their intake of toxin-containing food to obtain the optimal provision of nutrients while avoiding harm from the toxins. Such optimisation has been demonstrated in farm animals (Kyriazakis *et al.* 1997) and is probably common for all animals.

While this general topic has not yet been studied systematically in humans, conditioned taste aversion has been documented in cancer patients receiving chemotherapy (Scalera 2002). Combining a study of dietary patterns in healthy female volunteers (Cade *et al.* 2004) with genetic testing (Anonymous 2003) indicated nutrient/toxicant optimisation in people with haemochromatosia, accumulation of excessive levels of iron due to a genetic defect in iron excretion. Post-menopausal homozygotes for the C282Y mutation showed significantly lower intake of red meat than other women in the same age group, even though they were not consciously aware that high-iron foods were the cause of their symptoms.

Nevertheless, in food plants such as potatoes, toxicants regularly reach such high levels that a single meal can cause unpleasant symptoms in sensitive persons, although serious cases (more than a few hours of nausea and/or diarrhoea) are extremely rare, and no cases have been reported in developed countries for more than two decades (Percival and Dixon 1997). Many of the plant toxicants are phytoalexins, which means that they accumulate in varying amounts in response to mechanical damage, an infection or other stress conditions, so the concentrations within the same plant often vary by more than a factor of 100 depending on plant age and sample site (Morrissey and Osbourn 1999).

In terms of organic food quality, the question is then whether high, acutely toxic concentrations occur in the relevant plant foods and if so, what production factors are important to predict and preferably prevent this from happening, or if other measures can be used to alleviate the harmful effects.

In temperate countries, most reports of the occurrence of toxic levels of plant toxicants refer to furanocoumarins from parsnip or celeriac or glycoalkaloids from potatoes. Both these compound types accumulate when the roots or tubers, respectively, are subjected to mechanical or other damage, which can happen during or after transport to the retailer, independent of the production system. The few existing data, mostly unpublished, indicate that organically grown, undamaged material normally has somewhat higher average levels of these toxicants than conventionally grown crops, and that these average levels are well below the established safe limits, e.g. 200 mg/kg for glycoalkaloids in potatoes (Hajslova *et al.* 2005). However, a higher base level could indicate a higher resilience to damage, and the study of potatoes found that despite a 20% higher average level in the organic samples, most of the few samples near or exceeding the safety limit were conventionally grown. A recent survey of parsnips in Sweden (J. Hajslova pers. comm., 2005) showed equal levels in organic and conventionally grown, fresh undamaged material, but that the increase after damage or storage was significantly lower for organic than for conventional crops. In contrast, a UK survey of material collected in 1991–1992 found higher levels in both undamaged and damaged organic samples (Anonymous 1996), although neither study included information about variety, origin or storage history before purchase.

Under tropical conditions, the most prominent source of natural plant toxicants is cassava, which contains toxic cyanogenic glycosides. In contrast to the vegetables produced in temperate areas, the risk of poisoning, specifically the syndrome tropical spastic paraparesis (konzo), is not directly linked with the plant itself but is determined by other factors, namely the processing of the tubers and the availability of essential amino acids in the diet (since detoxification of cyanogenic glycosides consumes sulfur-containing amino acids) (Swenne *et al.* 1996). Both can be jeopardised in subsistence agriculture on depleted soils, particularly under adverse conditions such as drought (Kaiser 2002), while the content of toxicant is seen as an asset under normal conditions (Chiwona-Karltun *et al.* 1998). For tropical smallholders growing food for their family's own consumption, the possible significance of organic farming methods for prevention of cassava poisoning is thus related to the ability of these methods to preserve soil fertility and nutritional diversity of the overall diet (Brandt and Kidmose 2002), rather than any direct effect on the content in the plant.

Overall, no recent data indicate any particular risk of toxic symptoms to consumers from natural plant toxicants, and some hypotheses, if they are confirmed, could point to organic growing conditions as a measure that could further reduce the risk. However, since the most effective protection is simply to stop eating a dish if it makes one feel sick, the issue of organic production methods is of little direct significance for this aspect of food quality.

Beneficial nutritional properties or other positive impacts on health

Direct measurements of effects on health of animals or humans

To show definitively that one farming method results in food with a beneficial effect on health compared with food produced by a different method, it is necessary to measure something known to be directly related to the health of the consumer. As a result of practical, financial and ethical constraints, reported studies of this type have been primarily animal feeding studies, short-term human intervention studies or epidemiological studies. Until now, the results of these studies have not been particularly definitive. Several published animal feeding studies have shown significant effects on one or the other health related aspect, as reviewed in Woese *et al.* (1997), O'Doherty Jensen *et al.* (2001), Bourn and Prescott (2002), Food Standards Agency (2002), Soil Association (2002), Williams (2002), AFSSA (2003), BMVEL (2003), Kouba (2003), Lotter (2003) and Magkos *et al.* (2003). However, the effects were not always consistent, and some effects, such as the capacity of rodents to bear large litters, are difficult to relate to human health, while the failure to detect effects in most short-term human studies just shows that such studies are able to detect only the influences of treatments that affect health substantially.

One short-term controlled-feeding study on humans did show effects on a central biomarker, comparable to a substantial change in intake of vegetables (Grinder-Pedersen *et al.* 2003), which does indicate a definitive health benefit of the organic treatment. Unfortunately, the study contained a design error (different varieties of vegetables were chosen from the two systems) that substantially weakened this otherwise important conclusion. However, together with two other recent studies, it indicates possible reasons for the failures of previously published studies to provide clear and definitive evidence for any definitive links between production methods and human health. The study also indicated methods for how to reach a better understanding of the impact of food production systems on human health. These two studies are the above-mentioned rat feeding study by Finamore *et al.* (2004), and another recent study (Lauridsen *et al.* 2005).

Grinder-Pedersen *et al.* (2003) showed that the biomarker for protein oxidation in blood samples is sufficiently sensitive to detect differences in human subjects caused by small differences in diet (irrespective of whether this was vegetable variety, production method or the interaction of these factors). Therefore, it is relevant to include this biomarker in future studies of food and health in general, and studies on the effects of production systems in particular. Similarly, Finamore *et al.* (2004) showed that lymphocyte proliferative capacity can differentiate between the effects of completely matched diets only differing in production factors, although this marker is less generally applicable since it requires that the animal is sacrificed. Lauridsen *et al.* (2005) showed that rats fed diets constructed from materials produced in three different production systems differed with regard to their sleep patterns (organically fed ones slept with less interruptions during the day), content of immunoglobulin A (IgA) in blood (lowest in those fed conventional feed) and accumulation of adipose tissue (most fat was on the bodies of rats fed conventionally grown feed). Each of these studies also evaluated a range of other health measures without finding any differences. Although neither study proved definitive benefits of foods from either system, they demonstrate two important conclusions:

1 it is possible to detect health impacts that are definitively due to the production methods; and
2 all of the five markers of health that they indicate as relevant for this purpose have generally not been tested in earlier studies.

A simple explanation of the failure of previous studies to detect any differences could be as a result of these studies not evaluating the relevant markers for health. Four of the markers (except lymphocyte proliferative capacity) can be assessed non-invasively (sleep, accumulation of adipose tissue) or in blood samples (IgA, protein oxidation), and are therefore suitable for use in human studies. In addition, all the markers can be assessed on a range of different animal species.

In this context, it is particularly interesting that to date, one of the most definitive studies of humans by Alm *et al.* (1999) compared the frequency of atopic disorders (allergies) in children from anthroposophic schools (based on Rudolf Steiner's philosophy) with children from neighbouring public schools, and found that symptoms of allergy (current or past) was significantly lower among children attending anthroposophic schools. The children at anthroposophic schools ate predominantly organic food and substantial amounts of fermented vegetables, used antibiotics restrictively, had few vaccinations and were breastfed for longer. While it is not possible to identify a single factor to explain the observed difference among these children, the central link is the immune system, and that two of the four differing health aspects in the controlled animal studies (IgA content in blood, lymphocyte proliferative capacity) also relate to the immune system. A recent, more extensive study, PARSIFAL, with a similar design, confirmed this consequence of differences in lifestyle/diet across four European countries (Alfvén *et al.* 2006). Similarly, several early organic farming pioneers described improved disease resistance among animals and humans when consuming organic diets, as reviewed by Magkos *et al.* (2003). Such reports do not meet the standards of modern scientific investigations, and therefore should not be considered evidence of anything other than the beliefs of their authors, but if future controlled scientific studies confirm that food production methods do affect disease resistance of those consuming the food, these early observations may be seen as reflecting long-term consistent trends.

Overall, these studies show that despite the failure of most studies to show definitive direct effects on health, production methods probably affect food quality to the extent that they have a significant impact on health. These studies show that there is now a good basis for designing studies that can elucidate which production factors are important in this regard, and that the next step is to define and test these factors.

Indirect measurements of effects on health (content of beneficial substances)

Most studies intending to assess effects of production methods on food quality have done so by analysing the nutrient content and assuming that it would somehow be possible to translate these data into a ranking of effect on health. These studies, reviewed in detail by Woese *et al.* (1997), O'Doherty Jensen *et al.* (2001), Bourn and Prescott (2002), Soil Association (2002), Williams (2002), BMVEL (2003) and Magkos *et al.* (2003), have shown systematic effects, which can be summarised as follows.

In terms of levels of compounds indicated as positive for health, the composition of plants that obtain much of their nutrients from slowly released sources such as plant residues or compost, tend to differ from those provided large amounts of easily available mineral fertilisers as:

- higher levels of ascorbic acid (vitamin C);
- lower levels of nitrate;
- lower levels of total N (often expressed as 'protein');
- higher proportion of essential amino acids in protein;
- higher zinc (Zn) to phytate ratios (on tropical soils);
- lower levels of β-carotene; and
- higher levels of plant secondary metabolites.

These differences relating to plant production methods are typically less than 50%, and are therefore lower than typical levels of variation resulting from other factors such as variety, maturity or climate. Since organic farming generally differs from conventional farming in this aspect of plant nutrition, these trends are seen consistently in comparisons of organic and conventional produce, in particular in controlled studies where the other factors can be kept constant. These trends reflect general aspects of plant physiology (Stamp 2003), for example, they are also consistently reported in studies comparing different organic treatments or different conventional ones. If the nutrient availability patterns differ among treatments, then a few studies showing different trends should not be given too much weight (e.g. Brandt and Mølgaard 2001, Magkos *et al*. 2003).

Correspondingly, products from animals fed a large proportion of grass or other relevant roughage have higher:

- levels of β-carotene and other carotenoids, such as lutein;
- proportions of conjugated linoleic acids in the fat;
- proportions of polyunsaturated fatty acids in the fat; and
- levels of vitamin E, in particular the active, natural isomer (e.g. Dhiman *et al.* 1999, Nielsen *et al*. 2004).

However, as reviewed by Willet (1994), very little is certain about the causal connections between food composition and health, in cases where the diet does not contain harmful levels of a toxin, and contains adequate amounts of all relevant nutrients, which is almost always the case for human diets in affluent countries where most organic food is consumed. As a consequence, it is rarely possible to definitively determine that a particular compositional difference also implies a difference in impact on health (Brandt *et al*. 2004). However, that science cannot yet determine from a (rarely complete) list of contents which food is best for health does not necessarily mean that all foods are equal. Nor does it prove that differences on health effects (as described above) must be due to properties other than chemical composition, as some authors suggest (Meier-Ploeger *et al*. 2004). The only definitive conclusion is that it is not yet known which food components are the distinguishing ones for health. For example, if you follow all the official dietary recommendations, including eating 500–600 g of vegetables and fruit every day, it will prolong your life by 1–2 years compared with an average European diet (van't Veer *et al*. 2000). But only 200 g of vegetables and fruit are needed to provide the recommended dose of relevant vitamins and nutrients (Ali and Tsou 2000), the reason for the additional benefits from the further 300–400 g is not yet known to science (Brandt *et al*. 2004), and it is not yet known if apples are better than carrots, or if fresh carrots are better than cooked carrots. Whether organically grown carrots are better than conventionally grown ones would be more difficult to determine.

It may be unexpected that the plant secondary metabolites and nitrate are ranked as beneficial compounds here, since nitrate was traditionally considered harmful irrespective of source, and many secondary metabolites are best known as toxicants (see *Naturally occurring toxins – plant toxins*). However, nitrate in vegetables is not associated with any diseases and may have direct, positive effects on human and animal health by protecting against harmful bacteria (McKnight *et al.* 1999), the most substantial evidence being the discovery of active uptake and circulation of nitrate through the salivary glands. Whereas no subsequent papers have disputed the findings of McKnight *et al.* (1999), the safety guidelines on nitrate have not been revised. This illustrates how impossible it would be to model the impact on health of any increase or decrease of a component such as nitrate, when there is not even consensus on whether it should be considered beneficial or harmful for health.

Similarly, there are many indications that secondary plant metabolites are responsible for many of the otherwise enigmatic beneficial effects of vegetables and fruit. One argument is that they are the only components unique to these types of foods; another is that they exert an impressive variety of physiological effects, which makes it likely that at least some of these effects are positive, and outweigh other, negative effects (Dillard and German 2000, Brandt *et al.* 2004). Many scientists believe that the antioxidant effects of phenolics, carotenoids and related plant compounds are responsible for health benefits, but this hypothesis has not been neither proven nor consistently supported by any recent evidence (Stanner *et al.* 2003). This indicates that the documented benefits of vegetables and fruits probably result from the properties of plant secondary metabolites other than their antioxidant capacity (Brandt *et al.* 2004).

The levels of plant secondary metabolites/plant toxicants are more strongly and systematically determined by the production system than the other factors on the list. There is good consensus among scientists studying the basic interaction principles between plant resistance and the environment that high nutrient availability generally reduces the accumulation of these defence compounds, as well as resistance to diseases and pests (Stamp 2003). There are numerous observations, although surprisingly few scientific reports, that organically managed crops are less susceptible to diseases and pests than conventionally managed ones, if no pesticides are applied. When pesticides are used in conventional systems, the lower susceptibility is revealed as similar infection rates in comparable crops (van Bruggen 1995) or sometimes even higher infection rates in conventional crops (Birzele *et al.* 2002). The higher resistance of organic crops is possibly a combination of nutrient management effects with selection for resistant varieties and other factors that support the development of plant defence mechanisms, since organic farmers have been forced to observe and use any option that improved survival of the crop. However, in terms of impact on food quality, it may be less important if a particular plant is resistant due to genetic or environmental factors, as long as both mechanisms imply a higher level of health-promoting secondary metabolites (Brandt Mølgaard 2001). Very few data are available, since most studies have focused on nutrients or antioxidants. However, some antioxidants are also defence compounds and are therefore likely to have health impacts through mechanisms other than antioxidant capacity (Brandt *et al.* 2004). Some examples include a preliminary study of wine, where the resveratrol content was on average 26% higher in organic than in conventional wines in paired comparisons of the same grape variety (with a range of –10% to +50%), while variety averages differed from between 0.1 and 28 ppm (Levite *et al.* 2000). Weibel *et al.* (2000) found an 18% higher phenolic compound content (mainly protein-binding condensed tannins) in organic than in conventional apples in paired comparison of the variety Golden Delicious. In a German study, the content of glucoraphanin in broccoli obtained from supermarkets and organic food shops was compared. The organically grown produce contained between two and six times higher levels of glucoraphanin than the conventional, although as a survey these data can only be seen as indicating a trend (Adam 2002). Glucoraphanin is one of the few well-documented health promoting plant defence compounds.

Even if it became possible to precisely model the effect of these components on human health, the trends described cannot be used to claim that organic is always better or worse than conventional, due to the overlap between nutrient availability levels in organic and conventional systems (Figure 13.1). But it would then be possible to use compositional analyses as a tool to ensure that the quality of organic products was assured and preferably improved, and to thus claim that it is better than some defined level, even if some conventional products may also be just as good for health.

Regarding the compositional differences shown for animal products, whether they are important for health depends, as for the plants, on the overall composition of the diet of the people who eat them. The vitamin E content in milk is far too small for relevant differences to affect health (Nielsen *et al.* 2004), and too little is known about the dose-response relations of the impact of conjugated linoleic acids on health. However, the increased vitamin E level may still be important to prevent oxidation of the fat, a problem that can be exacerbated by increased levels of polyunsaturated fatty acids (Dhiman *et al.* 1999, Nielsen *et al.* 2004). However, while oxidised milk is clearly not good for health, its rancid taste and smell allows detection and rejection before consumption and thus prevents harm to health, similar to plant toxicants. Also in line with the plants, while the use of roughage is clearly more extensive in organic farming, some conventional farmers use almost identical feed compositions and are therefore likely to produce the same quality of products in this respect.

For practical reasons the plants of organic producers need to stay healthy, so farmers are unlikely to adopt new practices if they observe increased susceptibility to diseases and pests. If the above-listed hypotheses are substantiated, this will provide a guarantee that possible health advantages are retained even when new methods are adopted. There is, however, a risk that the development or adoption of effective methods to prevent diseases and pests, which do not depend on the intrinsic resistance of the plants, could relax this selection and thus lead to less health-protective plant composition. Awareness needs to be raised about monitoring plant resistance to diseases and pests as a key indicator not only of production efficiency but also of possible health benefits (and no harm will have been done if this turns out to be wrong).

A special case, and in many ways particularly important, is the effect on mineral balance of using slowly releasing phosphorus (P) from sources such as plant residues (from the previous crop) or phosphate rock for cereals grown in tropical low-phosphorus soils. Under these conditions, fertilisation with readily available forms of P such as superphosphate is common practice in conventional farming. Three independent studies using different methods and concepts all showed that when treatments relevant for organic farming were the main source of P, the ratio of Zn to phytate (phytic acid) was substantially higher than when the plants received phosphate salts (Ali and Harland 1991, Buerkert *et al.* 1998, Ryan *et al.* 2004). The role of phytate in plants is to store P in a way that makes it less available to herbivores, so it is not surprising that this substance accumulates in plants in response to P fertilisation. It is also well known that increasing the phytate content in grain decreases the bioavailability of Zn, and that Zn deficiency is a widespread malnutrition problem for both humans and livestock in poor areas of developing countries (Grases *et al.* 2001). This represents one case where the link between food composition and health is well understood. The interesting aspect is that even under similar yield levels (5–50% lower than the compared conventional systems), the change in nutritional value caused by the form of fertilisation can be great enough to change Zn availability from nutritionally adequate to a level likely to make a diet deficient in this nutrient. The average yield level at four organic farms in Australia (Ryan *et al.* 2004) was 2.4 tonne per ha, while millet in Niger fertilised only with plant residues produced 1.0 tonne per ha (Buerkert *et al.* 1998). These yields are substantially higher than the average figures for Africa of 1.7 and 0.7 tonnes per ha for maize and millet respectively (FAO 2004), often cited by biotechnology scientists as an argument for introducing genetically modified crops. The present production in Africa is a composite of commercial conventional production using some fertiliser and pesticides, and traditional subsistence farming that depends on very long fallow periods (10–30 years or more) to fully restore fertility after a few years of no-input farming. However, few farmers in developing countries use the methods developed in organic farming to preserve and improve soil fertility without expensive inputs. Since commercial cereal farming tends to require extensive subsidies as a result of the high costs of fertilisers and pesticides, and extensive fallow is no longer possible when population densities rise (Buerkert *et al.* 1998), based on the scientific evidence, only organic methods have demonstrated the ability to improve both yield and nutritional quality at the same time (Brandt and Kidmose 2002).

Perspectives

Once it becomes possible to determine some of the consequences for human health of the methods used for food production, and if the organic methods turn out to have a positive effect, an immediate result would very likely be increased demand for organic food. At the same time, such knowledge is also likely to lead to changes in farming methods in either organic or conventional production systems or both, since both farmers and regulating authorities are motivated to optimise the health value of all agricultural products, once it becomes known how to. In the slightly longer run, this could easily diminish or even abolish any advantage existing for organic food, by enabling other systems to improve. Thus, it is quite impossible to predict the long-term consequences of such research for organic agriculture. Nevertheless, it will lead to improved food safety and quality for the consumer.

Rather than focusing on specific safety issues, many consumers as well as producers see organic food as representing the precautionary principle on their behalf (Torjusen *et al.* 2004). That organic principles effectively protected against BSE is perceived as an indication that they could also protect against other, as yet unknown threats to health, which may develop from the various types of 'unnatural' technology used in modern agriculture. Some authors even consider this type of 'naive' conviction as a threat to consumer safety and health, by diverting focus to unknown, possibly imagined safety risks rather than concentrating on efforts to improve the overall diet, such as increasing vegetable intake, which would have greater and more certain health benefits (Avery 1998, Trewavas 2001 2004).

Although any amount of data probably will not affect the convictions of those who represent the more extreme views at either end, this Chapter indicates where consistent patterns can be detected instead of just isolated observations, and points towards a future where knowledge regarding cause and effect will guide efforts to improve food quality in organic production and other systems.

References

Adam S. 2002. Vergleich des Gehaltes an Glucoraphanin in Broccoli aus konventionellem und aus ökologischem Anbau. In: *Bundesforschungsanstalt für Ernährung (Hrsg.) Jahresbericht 2001*. Bundesforschungsanstalt für Ernährung und Lebensmittel, Karlsruhe.

AFSSA [Agence Française de Securite Sanitaire des Aliments] 2003. *Evaluation des risques et bénéfices nutritionnels et sanitaires des aliments issus de l'agriculture biologique*. AFSSA, Maisons Alfort. <http://www.afssa.fr/Object.asp?IdObj=15490&Pge=0&CCH=040309183309:26:4&cwSID=B89BD2CA272C410EABF11B88462C59EB&AID=0>. Accessed 21/8/05.

Alfvén, T., Braun-Fahrländer, C., Brunekreef, B., von Mutius, E., Riedler, J., Scheynius, A., van Hage, M., Wickman, M., Benz, M.R., Budde, J., Michels, K.B., Schram, D., Üblagger, E., Waser, M., Pershagen, G., the PARSIFAL study group. 2006. Allergic diseases and atopic sensitization in children related to farming and anthroposophic lifestyle – the PARSIFAL study. *Allergy* 61: 414–421.

Ali, H.I. and Harland, B.F. 1991. Effects of fiber and phytate in sorghum flour on iron and zinc in weanling rats: a pilot study. *Cereal Chemistry* 68: 234–238.

Ali, M, and Tsou, S. 2000. The integrated research approach of the Asian Vegetable Research and Development Center (AVRDC) to enhance micronutrient bioavailability. *Food and Nutrition Bulletin* 21: 472–481.

Alm, J.S., Swartz, J., Lilja, G., Scheynius, A., Pershagen, G. 1999. Atopy in children of families with an anthroposophic lifestyle. *Lancet* 353: 1485–1488.

Anonymous 1996. Inherent natural toxicants in food. *Food Surveillance Paper No. 51,* Ministry of Agriculture, Fisheries and Food, The Stationery Office, London.

Anonymous 2003. N05023: *Influence of Genetic Mutations on Iron Status Linked to Dietary Intake – From the UK Women's Cohort Study*. Food Standards Agency, London. <http://www.food.gov.uk/science/research/researchinfo/nutritionresearch/optimalnutrition/n05programme/n05listbio/n05023>. Accessed 21/8/05.

Avery, D.T. 1998. The hidden dangers of organic food. *American Outlook* Fall: 19–22.

Baker, B.P., Benbrook, C.M., Groth, E. and Benbrook, K.L. 2002. Pesticide residues in conventional, integrated pest management (IPM)-grown and organic foods: insights from three US data sets. *Food Additives and Contaminants* 19: 427–446.

Bateman, B., Warner, J.O., Hutchinson, E., Dean, T., Rowlandson, P., Gant, C., Grundy, J., Fitzgerald, C., Stevenson, J. 2004. The effects of a double blind, placebo controlled, artificial food colourings and benzoate preservative challenge on hyperactivity in a general population sample of preschool children. *Archives of Disease in Childhood* 89: 506–511.

Birzele, B., Meier, A., Hindorf, H., Kramer, J. and Dehne, H.W. 2002. Epidemiology of Fusarium infection and deoxynivalenol content in winter wheat in the Rhineland, Germany. *European Journal of Plant Pathology* 108: 667–673.

BMVEL [Bundesministerium für Verbraucherschutz, Ernährung und Landwirtschaft] 2003. *Bewertung von Lebensmitteln verschiedener Produktionsverfahren*. BMVEL-Forschung.

Bourn, D. and Prescott, J. 2002. A comparison of the nutritional value, sensory qualities, and food safety of organically and conventionally produced foods. *Critical Reviews in Food Science and Nutrition* 42: 1–34.

Brandt, K., Christensen, L.P., Hansen-Møller, J., Hansen, S.L., Haraldsdóttir, J., Jespersen, L., Purup, S., Kharazmi, A., Barkholt, V., Frøkiær, H. and Kobæk-Larsen, M. 2004. Health promoting compounds in vegetables and fruits, *Trends in Food Science and Technology* 15: 384–393.

Brandt, K. and Kidmose, U. 2002. Nutritional consequences of using organic agricultural methods in developing countries. In: Cakmak, I., Graham, R.D. and Welch, M (eds) *Impacts of Agriculture on Human Health and Nutrition*. EOLSS Publishers, Oxford.

Brandt, K.and Mølgaard, J.P. 2001. Organic agriculture: does it enhance or reduce the nutritional value of plant foods? *Journal of the Science of Food and Agriculture* 81: 924–931.

Buerkert, A., Haake, C., Ruckwied, M. and Marschner, H. 1998. Phosphorus application affects the nutritional quality of millet grain in the Sahel. *Field Crops Research* 57: 223–235.

Cade, J.E., Burley, V.J., Greenwood, D.C. and the UK Women's Cohort Study Steering Group. 2004. The UK Women's Cohort Study: comparison of vegetarians, fish-eaters and meat-eaters. *Public Health Nutrition* 7: 871–878.

Calabrese, E.J. 2004. Hormesis: from marginalization to mainstream. A case for hormesis as the default dose-response model in risk assessment. *Toxicology and Applied Pharmacology* 197: 125–136.

Calabres, E.J. and Blain, R. 2005. The occurrence of hormetic dose responses in the toxicological literature, the hormesis database: an overview. *Toxicology and Applied Pharmacology* 202: 289–301.

Chiwona-Karltun, L., Mkumbira, J., Saka, J., Bovin, M., Mahungu, N.M., Rosling, H. 1998. The importance of being bitter – a qualitative study on cassava cultivar preference in Malawi. *Ecology of Food and Nutrition* 37: 219–245.

Couzin, J. 1998. Cattle diet linked to bacterial growth. *Science* 281: 1578–1579.

Cross-Mellor, S., Clark, S.N.D.A. and Ossenkopp, K.-P. 2004. Rapid toxin-induced gustatory conditioning in rats: separate and combined effects of systemic injection or intraoral infusion of lithium chloride. *Behavioural Brain Research* 154: 423–430.

Dengate, S. and Ruben, A. 2002. Controlled trial of cumulative behavioural effects of a common bread preservative. *Journal of Paediatrics and Child Health* 38: 373–376.

Dhiman, T.R., Anand, G.R., Satter, L.D., Pariza, M.W. 1999. Conjugated linoleic acid content of milk from cows fed different diets. *Journal of Dairy Science* 82: 2146–2156.

Diehl, J.F. 2002. Some established facts and some new concepts in food toxicology – a review. *Acta Alimentaria* 31: 355–369.

Diez-Gonzalez, F., Callaway, T.R., Kizoulis, M.G. and Russell, J.B. 1998. Grain feeding and the dissemination of acid-resistant *Escherichia coli* from cattle. *Science* 281: 1666–1668.

Dillard, C.J. and German, J.B. 2000. Phytochemicals: nutraceuticals and human health. *Journal of the Science of Food and Agriculture* 80: 1744–1756.

Doll, S., Valenta, H., Danicke, S. and Flachowsky, G. 2002. Fusarium mycotoxins in conventionally and organically grown grain from Thuringia/Germany. *Landbauforschung Volkenrode* 52: 91–96.

Elmholt, S. 2003. Ecology of the ochratoxin A producing *Penicillium verrucosum*: occurrence in field soil and grain with special attention to farming system and on-farm drying practices. *Biological Agriculture and Horticulture* 20: 311–337.

European Union 2001. *Organic Farming in the EU: Facts and Figures*. European Union, Brussels. <http://europa.eu.int/comm/agriculture/qual/organic/facts_en.pdf>. Accessed 21/8/05.

FAO 2004. *FAOSTAT Home Page*. Food and Agriculture Organization of the United Nations, Rome. <http://faostat.fao.org/>. Accessed 16/1/06.

Food Safety Authority of Ireland 2004. *Investigation into Levels of Dioxins, Furans, PCBs and Some Elements in Battery, Free-range, Barn and Organic Eggs*. Food Safety Authority of Ireland, Dublin.

Food Standards Agency 2002. *Report of the Workshop on Research and Surveys to Inform Consumer Choice Between Organic and Conventionally Produced Food*. Food Standards Agency, UK.

Finamore, A., Britti, M.S., Roselli, M., Bellovino, D., Gaetani, S. and Mengheri, E. 2004. Novel approach for food safety evaluation. Results of a pilot experiment to evaluate organic and conventional foods. *Journal of Agricultural and Food Chemistry* 52: 7425–7431.

Franz, E., van Bruggen, A.H.C. and Semenov, A.M. 2004. Risk-analysis of human pathogen spread in the vegetable industry: a comparison between organic and conventional production chains. In: van Boekel, M.A.J.S., Stein, A. and van Bruggen, A.H.C. (eds) *Bayesian Statistics and Quality Modelling in the Agro-food Production Chain*. Kluwer Academic Publishers, Wageningen. pp. 81–94.

Franz, E., van Diepeningen, A.D., de Vos, O.J. and van Bruggen, A.H.C. 2005. Effects of cattle feeding regimen and soil management type on the fate of *Escherichia coli* O157:H7 and *Salmonella enterica* serovar *Typhimurium* in manure, manure-amended soil, and lettuce. *Applied Environmental Microbiology* 71: 6165–6174.

Grases F., Bartolome M.S., Prieto R.M. and March J.G. 2001. Dietary phytate and mineral bioavailability. *Journal of Trace Elements in Medicine and Biology* 15: 221–228.

Grinder-Pedersen, L., Rasmussen, S.E., Bügel, S., Jørgensen, L.V., Dragsted, L.O., Gundersen, V. and Sandström, B. 2003. Effect of diets based on foods from conventional versus organic production on intake and excretion of flavonoids and markers of antioxidative defense in humans. *Journal of Agricultural Food and Chemistry* 51: 5671–5676.

Hajslová, J., Schulzová, V., Slanina, P., Janné, K., Hellenäs, K.E. and Andersson, C. 2005. Quality of organically and conventionally grown potatoes: Four-year study of micronutrients, metals, secondary metabolites, enzymic browning and organoleptic properties. *Food Additives and Contaminants* 22: 514–534.

Hald, T., Lo Fo Wong, D.M.A. and Wingstrand, A. 1999. Zoonotiske *Salmonella* i alternativ husdyrproduktion. *Alimenta* 9: 7.

Harker, F.R. 2004. Organic food claims cannot be substantiated through testing of samples intercepted in the marketplace: a horticulturalist's opinion. *Food Quality and Preference* 15: 91–95.

Harnly, M.E., Petreas, M.X., Flattery, J. and Goldman, L.R. 2000. Polychlorinated dibenzo-p-dioxin and polychlorinated dibenzofuran contamination in soil and home-produced chicken eggs near pentachlorophenol sources. *Environmental Science and Technology* 34: 1143–1149.

Hietaniemi, V., Kontturi, M., Ramo, S., Eurola, M., Kangas, A., Niskanen, M. and Saastamoinen, M. 2004. Contents of trichothecenes in oats during official variety, organic cultivation and nitrogen fertilization trials in Finland. *Agricultural and Food Science* 13: 54–67.

Hoyle, D.V., Shaw, D.J., Knight, H.I., Davison, H.C., Pearce, M.C., Low, J.C., Gunn, G.J. and Woolhouse, M.E.J. 2004. Age-related decline in carriage of ampicillin-resistant *Escherichia coli* in young calves. *Applied and Environmental Microbiology* 70: 6927–6930.

Johannessen, G.S., Froseth, R.B., Solemdal, L., Jarp, J., Wasteson, Y. and Rorvik, L.M. 2004. Influence of bovine manure as fertilizer on the bacteriological quality of organic Iceberg lettuce. *Journal of Applied Microbiology* 96: 787–794.

Jørgensen, .K, Larsen, E.H., Petersen, A., Lund, K.H., Hilbert, G., Andersen, N.L. 2000. *Kemiske forureninger. Overvågningssystem for levnedsmidler. 1993–1997.* Fødevaredirektoratet, Søborg.

Justesen, U., Knuthsen, P. and Leth, T. 1998. Quantitative analysis of flavonols, flavones, and flavanones in fruits, vegetables and beverages by high-performance liquid chromatography with photo-diode array and mass spectrometric detection. *Journal of Chromatography, A* 799: 101–110.

Kaiser, R. 2002. Endemic spastic paraperesis (konzo). *Nervenarzt* 73: 946–951.

Kouba, M. 2003. Quality of organic animal products. *Livestock Production Science* 80: 33–40.

Kyriazakis, I., Papachristou ,T.G., Duncan, A.J. and Gordon, I.J. 1997. Mild conditioned food aversions developed by sheep towards flavors associated with plant secondary compounds. *Journal of Chemical Ecology* 23: 727–747.

Lauridsen, C., Jørgensen, H., Halekoh, U., Christensen, L.P. and Brandt, K. 2005. Organic diet enhanced the health of rats. *DARCOF [Danish Research Centre for Organic Farming] Enews*. 1. <http://www.darcof.dk/enews/mar05/health.html>. Accessed 16/1/06.

Levite, D., Adrian, M. and Tamm, L. 2000. Preliminary results of resveratrol in wine of organic and conventional vineyards. In: Willer, H. and Meier, U. (eds.) *IFOAM 2000 – The World Grows Organic. 6th International Congress on Organic Viticulture 25–26 Aug. 2000, Basel Switzerland*. vdf Hochschulverlag AG an der ETH Zurich, Basel. pp. 256–257.

Lotter, D.W. 2003. Organic agriculture. *Journal of Sustainable Agriculture* 21: 59–128.

Lund, B .M. 2002. *Managing Farm Manures for Food Safety*. Institute of Food Research, Norwich. <http://www.ifr.ac.uk/science/consultations/manure.html>. Accessed 16/1/06.

Magkos, F., Arvaniti, F. and Zampelas, A. 2003. Organic food: nutritious food or food for thought? A review of the evidence. *International Journal of Food Sciences and Nutrition* 54: 357–371.

McKnight, G.M., Duncan, C.W., Leifert, C. and Golden, M.H.N. 1999. Dietary nitrate in man – friend or foe. *British Journal of Nutrition* 81: 349–358.

Meier-Ploeger, A., Strube, J., Kahl, J. and Busscher, N. 2004. Complementary methods of food quality determination – their value and validation. Elm Farm Research Centre, Newbery. <http://www.efrc.com/pdf/eqabstra.pdf>. Accessed 21/8/05.

Meier-Ploeger, A. 1996. A new definition of food quality. In: Stolton, S. and Dudley, N. (eds) *Seeking Permanence – 15 years and Into the Future*. Elm Farm Research Centre, Newbery. p. 34.

Morrissey, J.P. and Osbourn, A.E. 1999. Fungal resistance to plant antibiotics as a mechanism of pathogenesis. *Microbiology and Molecular Biology Reviews* 63: 708–724.

Mozafar, A. 1993. Nitrogen fertilizers and the amount of vitamins in plants – a review. *Journal of Plant Nutrition* 16: 2479–2506.

National Organic Program 2000. *NOP Program Standards*. Agricultural Marketing Service, United States Department of Agriculture. <http://www.ams.usda.gov/nop/NOP/standards.html>. Accessed 21/8/05.

Nielsen, JH, Lund-Nielsen, T and Skibsted, L. 2004. Higher antioxidant content in organic milk than in conventional milk due to feeding strategy. <http://www.darcof.dk/enews/sep04/milk.html>.

O'Doherty Jensen, K., Larsen, H.N., Mølgaard, J.P., Andersen, J.-O., Tingstad, A., Marckmann, P. and Astrup, A. 2001. *Økologiske fødevarer og menneskets sundhed*. Report on literature review coordinated by Institute of Human Nutrition, Royal Agricultural and Veterinary University, Denmark. DARCOF, Tjele.

Pedersen, H.L. and Bertelsen, M. 2002. Alleyway groundcover management and scab resistant apple varieties. In: Fördergemeinschaft Ökologischer Obstbau (ed.) *ECO-FRU-VIT. 10th International Conference on Cultivation Technique and Phytopathological Problems in Organic Fruit-Growing and Viticulture*. Weinsberg, Germany 4–7 February 2002. Fördergemeinschaft Ökologischer Obstbau, Weinsberg. pp. 16–21.

Percival, G.C. and Dixon, G.R. 1997. Glycoalkaloids. In: D'Mello, J.F. (ed.) *Handbook of Plant and Fungal Toxicants*. CRC Press, Boca Raton. pp. 19–36.

Pussemier, L., Mohimont, L., Huyghebaert, A. and Goeyens, L. 2004. Enhanced levels of dioxins in eggs from free range hens; a fast evaluation approach. *Talanta* 63: 1273–1276.

QLIF 2006. QualityLowInputFood. <http://www.qlif.org/>. Accessed 16/1/06.

Ryan, M.H., Derrick, J.W. and Dann, P.R. 2004. Grain mineral concentrations and yield of wheat grown under organic and conventional management. *Journal of the Science of Food and Agriculture* 84: 207–216.

Sato, K., Bennedsgaard, T.W., Bartlett, PC., Erskine, R.J. and Kaneene, J.B. 2004. Comparison of antimicrobial susceptibility of *Staphylococcus aureus* isolated from bulk tank milk in organic and conventional dairy herds in the Midwestern United States and Denmark. *Journal of Food Protection* 67: 1104–1110.

Scalera, G. 2002. Effects of conditioned food aversions on nutritional behavior in humans. *Nutritional Neuroscience* 5: 159–188.

Schifferstein, H.N.J. and Ophuis, P.A.M.O. 1998. Health-related determinants of organic food consumption in the Netherlands. *Food Quality and Preference* 9: 119–133.

Schollenberger, M., Suchy, .S, Jara, H.T., Drochner, W. and Muller, H.M. 1999. A survey of Fusarium toxins in cereal-based foods marketed in an area of southwest Germany. *Mycopathologia* 147: 49–57.

Schollenberger, M., Jara, H.T., Suchy, S., Drochner, W. and Muller, H.M. 2002. Fusarium toxins in wheat flour collected in an area in southwest Germany. *International Journal of Food Microbiology* 72: 85–89.

Soil Association 2002. *Organic Farming, Food Quality and Human Health; A Review of the Evidence*. Soil Association, Bristol.

Stamp, N. 2003. Out of the quagmire of plant defense hypotheses. *The Quarterly Review of Biology* 78: 23–55.

Stanner, S.A., Hughes, J., Kelly, C.N.M. and Buttriss, J. 2003. A review of the epidemiological evidence for the 'antioxidant hypothesis'. *Public Health*. *Nutrition* 7: 407–422.

Swenne, I., Eriksson, U.J., Christoffersson, R., Kagedal, B., Lundquist, P., Nilsson, L., Tylleskar, T. and Rosling, H. 1996. Cyanide toxification in rats exposed to acetonitrile and fed a low protein diet. *Fundamental and Applied Toxicology* 32: 66–71.

Tikofsky, L.L., Barlow, J.W., Santisteban, C. and Schukken, Y.H. 2003. A comparison of antimicrobial susceptibility patterns for Staphylococcus aureus in organic and conventional dairy herds. *Microbial Drug Resistance-Mechanisms Epidemiology and Disease* 9: S39–S45.

Torjusen, H., Sangstad, L. O'Doherty Jensen, K. and Kjærnes, U. 2004. European consumers' conceptions of organic food: a review of available research. National Institute for Consumer Research, Nydalen.

Torner, H., Blottner, S., Kuhla, S., Langhammer, M., Alm, H., Tuchscherer, A. 1999. Influence of chlorocholinechloride-treated wheat on selected in vitro fertility parameters in male mice. *Reproductive Toxicology* 13: 399–404.

Trewavas, A. 2001. Urban myths of organic farming. *Nature* 410: 409–410.

Trewavas, A. 2004. A critical assessment of organic farming-and-food assertions with particular respect to the UK and the potential environmental benefits of no-till agriculture. *Crop Protection* 23: 757–781.

Tschape, H., Prager, R., Streckel, W., Fruth, A., Tietze, E. and Bohme, G. 1995. Verotoxinogenic *Citrobacter freundii* associated with severe gastroenterits and cases of hemolytic uremic syndrome in a nursery school-green butter as an infection source. *Epidemiology and Infection* 114: 441–450.

van Bruggen, A.H.C. 1995. Plant disease severity in high-input compared to reduced-input and organic farming systems. *Plant Diseases* 79: 976–984.

van't Veer, P., Jansen, M.C.J.F., Klerk, M. and Kok, F.J. 2000. Fruits and vegetables in the prevention of cancer and cardiovascular disease. *Public Health*. *Nutrition* 3: 103–107.

Weber, A., Bokmeier, H., Janssen, J., Strube, J. and Stolz, P. 2001. Pflanzenschutzmittelrückstä nde in Lebensmitteln aus ökologischer Herkunft im Vergleich zu nicht ökologischer Herkunft. *Lebensmittelchemie* 55: 113–136.

Weibel, F.P., Bickel, R., Leuthold, S. and Alföldi, T. 2000. Are organically grown apples tastier and healthier? A comparative field study using conventional and alternative methods to measure fruit quality. *Acta Horticulturae* 517: 417–426.

Williams, C.M. 2002. Nutritional quality of organic food: shades of grey or shades of green? *Proceedings of the Nutrition Society* 61: 19–24.

Willett, W.C. 1994. Diet and Health: What should we eat? *Science* 264: 532–537.

Woese, K., Lange, D., Boess, C. and Bögl, K.W. 1997. A comparison of organically and conventionally grown foods – results of a review of the relevant literature. *Journal of the Science of Food and Agriculture* 74: 281–293.

Chapter 14

Social responsibility in organic agriculture: learning, collaboration and regulation

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Introduction

> Social justice has not been an integral part of the construction of the organic movement (Guthman 2004). Yet, today we are witnessing the emergence of new movements or perhaps a rejuvenation of existing movements, that seek to promote fair trade and new codes of conduct. The introduction of new concepts such as chain transparency, food chain awareness, food miles, 'just food' and sweat shops, and the appearance of bestseller books like *Fast Food Nation,* suggest an increased public concern about food that transcends health, taste and price, to include the social costs of food production.

This Chapter provides an overview of social responsibility within the organic sector, referring to different conceptualisations and discussions underway. Against this backdrop, the focus on social justice issues, as embraced by leading organisations in the field is discussed (see *Social responsibility in the organic context*), and a three-pronged approach for addressing social responsibility is presented and advocated (see *A framework for approaching social responsibility in organic agriculture*). Regulation, collaboration and learning are argued as three necessary and (potentially) mutually reinforcing coordination mechanisms for fostering enhanced social responsibility throughout the organic sector and furthering the social agenda. Regulation and collaboration are explored, with several examples provided to illustrate current manifestations of how these mechanisms work. These are the more developed and active forces within the sector. A learning approach is articulated in more depth (see *Learning and social responsibility*), with nuances and challenges considered.

Because learning is a less-developed approach, we make a case for learning to be embraced more fully. The argument draws on learning theory and applies this theory to the reality of the challenges facing the sector with respect to social responsibility. Two types of learning are discussed: instrumental and emancipatory learning. Instrumental learning is learning *for* social responsibility, whereas emancipatory learning is learning *towards* social responsibility. Discussion on emancipatory learning describes the spectrum from 'big brother' to 'grassroots' learning and explores the role of conflict in this. Further, different levels of learning from interstakeholder to intrastakeholder and from micro- to meso- and macro- are all touched upon. A final section (see *A three-pronged approach to social responsibility*) reasserts the value of the three-pronged approach advocated and offers an example, internal control systems (ICS) for group certification in developing countries, to illustrate how regulation, collaboration and learning can overlap and reinforce one another to the benefit of all. This Chapter concludes with a reiteration of our argument that values the utilisation of all three coordination mechanisms, and places the discussion back into the larger agricultural and societal contexts.

Social responsibility in the organic context

It is no surprise that the technological revolution that swept through agriculture in the 1950s fuelled questions by some of the pioneers of organic agriculture. After all, they were concerned with the health of the soil, plants, animals and people, and were committed to maintaining farms that were small in scale, self sufficient and accepting of the 'natural' order. The commitment of such individuals and discreet organisations transformed organic agriculture from a rather loose concept into a social movement with associated farming methods in the last quarter of the 20th century. This movement intentionally placed itself as an alternative to mainstream agriculture. The consolidation of fringe movements and subsequent evolution of these movements into a more coherent whole, which took place in the second half of the 20th century, was very much the result of a two-way process of societal demands shaping organic agriculture, and the organic movement gradually influencing some sections of society. Over time, the philosophical roots of the movement have been translated into standards to guide systems of production and, with the rapid expansion of markets and the appeal of high prices, the organic 'movement' has emerged globally as a recognisable sector within agriculture. Producers and producer organisations, certifying bodies, processors and traders, service providers, various organic interest groups and a plethora of other players now constitute this sector.

The international growth and development of the organic sector can be seen as positive in terms of its contribution to sustainable agriculture and the triple goals of social responsibility, economic viability and environmental integrity. However, the global nature of this expansion and the likely absorption, appropriation and concentration of organic agriculture by conventional agriculture and its market structures, the so-called 'conventionalisation' of organic agriculture, and its consequences in terms of the original ideals of the organic movement, have been topics of recent intense discussion. The most rapid growth of organic farming has taken place in Europe. Michelsen (2001) described this growth as a breakthrough, whereby what was an obscure type of farming in the beginning of the 1980s had become an institutionalised form of production with its own dynamics in the market place by the year 2000 in some countries. The rising influence of the environmental movement over the same period leading to greater public interest in environmental matters, coupled with the prominence of a series of food safety concerns, are attributed to heightening consumer interest in organic products. The formal political recognition of the organic movement and ongoing policy formulations at the European Union (EU) level has complemented this growth process (Dabbert *et al*. 2004).

In the consumers' minds, personal well being, taste, environmental values of a general nature and animal welfare concerns have been the more important motivations for buying organic food as opposed to an adherence to organic principles (Dabbert *et al*. 2004). Social values and social justice criteria have not been expressed as distinct driving forces for consumer behaviour towards organic agriculture in Europe. In a country like Denmark, which has the highest consumption of organic products per capita in the world, a prerequisite for such high consumption is seen as a trustworthy and recognisable organic label, which guarantees that organic production rules have been observed (Wier *et al*. 2004). Public good attributes, such as improved animal welfare and environmental protection, were seen by most respondents as important features of organic production, even higher than private good attributes such as health. In the United States of America (USA), Allen and Kovach (2000) acknowledged that social and environmental relationships are not separable in practice, but went on to say that there was a disturbing invisibility of important social issues, such as labour relations and land tenure, within conventional agriculture as well as within its organic counterpart. Social responsibility considerations may have been integral to the visions of pioneers in the organic movement, both producers and consumers, but these have been neither well articulated nor codified. In 2002, the social justice chapter of the organic 'standards for standards', the International Federation of Organic Agriculture Movements (IFOAM) Basic Standards (IBS), was renegotiated and rewritten (see *A framework for approaching social responsibility in organic agriculture* for details).

Institutionalisation of 'organic' values

Since the 1920s in Europe, a distillation of organic values, ideology and principles of the social movement have developed into standards, rules, regulations and eventually national legislations (Rundgren 2002). The development of the sector from locally entrenched fringe movements to a more widely accepted alternative to conventional agriculture is a triumph, but not without compromises. The translation of organic movement values (Campbell and Liepens 2001) into measurable indicators for standard verification and legal requirements has allowed industrial agriculture to enter into organic production. As a result, some argue, value-laden private sector standards are becoming input-based recipes and prescriptions. There has been much debate and controversy over what has been termed the 'institutionalisation'(Kaltoft 1999, 2001), 'conventionalisation' (Hall and Mogyorody 2001), 'commoditisation' (Buck *et al*. 1997, Tovey 1997), 'scaling up' (Goodman 2000) or mainstreaming (Klonsky 2000) of organic agriculture. Concerns abound (Tovey 1997, Kaltoft 1999, Goewie 2002) that the widespread institutionalisation of organic agriculture is leading to an erosion and even loss of the movement's core values.

Figure 14.1 illustrates the relationship of organic agriculture within the agricultural sector and to society at large. Concepts of organic agriculture are socially constructed and 'circulated in a dynamic way that continually mirrors and reshapes the contexts in which the production and consumption of organic produce occurs' (Campbell and Liepens 2001, p. 26). This is also true of the social aspects of organic agriculture. The triangle housed within the organic sector (Figure 14.1) represents the social responsibility aspects of the movement, the three sides denote the three approaches we put forward as complementary (see *A framework for approaching social responsibility in organic agriculture*): learning, collaboration and regulation. The relationship to broader society and the agricultural sector is relevant as different perspectives of social responsibility within the organic agriculture movement are explored.

Despite the inception of organic agriculture as a counter movement to the modernising processes of agriculture in general, recent concerns have been expressed in Europe and the USA about organic agriculture beginning to resemble and being incorporated into conventional agriculture (Buck *et al*. 1997, Tovey 1997, Guthman 2004). In a more global context, particularly that of poorer farmers in developing countries, Alrøe and Kristensen (2004) raise the question as to whether it was important for organic agriculture to be retained as an opposition to modernising processes. Or can organic agriculture continue to modernise in its own way without compromising its original values and ideals, and its now more clearly articulated social responsibilities to citizens in poor and rich countries? Indeed, are there ways for organic

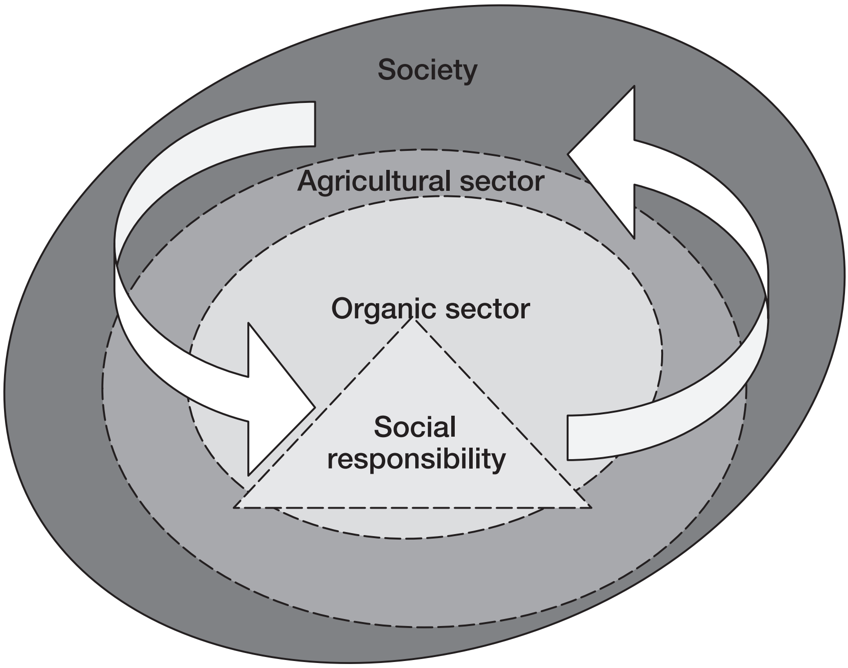

Figure 14.1 Positioning social responsibility in the organic sector. The arrows indicate the interconnectedness of the various contextual levels.

agriculture to pursue its own process, thereby contributing to a 'desirable' and socially responsible modernisation of the global agrifood sector, and thus to the whole of society?

As part of setting its directions for research and development of the organic sector, the Danish Research Centre for Organic Farming (DARCOF) identified three basic principles for action: the cyclical principle, the precautionary principle and the nearness principle. The nearness principle implied that social aspects of food production can be improved by nearness between producer and consumer. Applied at the local level, as indeed had been taking place when the organic industry was small and agriculture very uniform in a country like Denmark, production, processing and marketing systems were proximate and transparent, and social justice concerns were hardly expressed. If the nearness principle is extended to the wider organic sector at national and global levels, it seems sensible to argue that emotional nearness would substitute for physical or geographical nearness when it comes to social responsibility concerns (DARCOF 2000).

Localisation as an alternative to the globalising process of agriculture and as a way of re-establishing the proximity between producer and consumer has been attempted in organic agriculture and through several other related initiatives, such as farmers markets and community-supported agriculture. On the basis of studying 37 local agrifood initiatives in California, which as a State has a long history of such initiatives, Allen *et al.* (2003) concluded that social justice may be difficult to construct at a 'local' scale. Despite the wide recognition of the issue of social justice of labour as problematic in California, these researchers found that social justice concerns of the agrifood initiatives they studied were more to do with food access and support for small farmers than with justice for farm workers in terms of recognition, wage and job security. Questions related to the position of seasonal workers in organic farms in Europe have not been addressed through research either. Paucity of information on social problems in organic farming and the lack of in-depth studies on working conditions for labour have been

Box 14.1 Strategic marketing of organic produce (ALDI Australia 2006)

Do you sell organic products?
At ALDI our policy is to restrict our assortment to most-needed products. By concentrating our buying power on these high-demand items we provide unbeatable value to our customers. If demand for organic products continues to grow throughout the general population, we will include these in our product range – provided we can guarantee consistently high quality.

highlighted by Oppermann (2003). A Danish study (Hansen 2004) on changes in the working environment for organic farmers revealed that not only the physical workload tends to increase on organic farms, but also the amount of psychosocial stress. The latter is mainly the result of the additional administrative workload and dealing with changes in market conditions, farm size and employee relations (Hansen 2004).

On the consumption side too, inequalities in access to food seem to be brought out by organic and other alternate food systems. The higher prices for organic food compared to conventional food make organic food beyond the reach of poor people. Allen (1999) points out that it was the industrialised food systems that reduced income-related class differences in food consumption and made food more accessible to all. Ironically, the ways in which the emerging alternate food systems are structured threaten to reverse or break down this levelling. Goodman (2004), commenting on the new rural development paradigm of Western Europe and the new modes of food provision within it such as short food-supply chains, speaks of these initiatives as overlooking social justice issues. In the long run they will favour a new multitiered food system differentiated by income and class, and Goodman (2004) refers to those citizens unable to secure access to safe, quality and nutritious food as the 'missing guests' at the table. Ironically perhaps, there are now low-budget supermarkets such as the ALDI Group that offer very affordable organic products for a specific niche of 'price aware, light green, soft bio-consumers' (see Box 14.1 for a statement from ALDI on supply of organic produce). However, these same low-budget supermarkets have a poor track record when it comes to workers' rights and providing adequate worker compensation.

The driving principles of low-budget supermarkets are obviously different from those of the certifying bodies of organically grown products. If there is a demand for a product, they will find a supplier. This leads to dilemmas for the organic farming sector. Berlin-based Märkisches Landbrot, one of Germany's largest organic bread and muesli producers, typifies a perhaps overly principled stance. The company will not offer discounts to supermarket chains that are looking for organic suppliers. Märkisches Landbrot's marketing director Sabine Jansen says that to offer cuts to the big chains 'would do in the natural food stores'. For the same reason, *Demeter* is unwilling to supply goods it certifies to nationwide discount chains like Plus or ALDI. The result is that the organic products that fill Germany's bargain grocery chains and upscale biosupermarkets increasingly come from somewhere else (Anonymous 2003).

A question arising from the social justice concerns referred to above in connection with contemporary organic agriculture sectors in Europe and the USA would be the degree to which some of these inequalities will be reproduced in 'developing' countries as their organic sectors begin to be shaped by the consumption patterns and institutional structures of the 'developed' countries. Raynolds (2004) reviewed the rising world organic trade and the expanding agrifood networks between developing and developed countries. The rigorous controls in place and the developed countries' market demands for continuous supply of quality goods no doubt leave the small producer in developing countries with few alternatives. Raynolds (2004) proposes the integration of these small-scale peasant producers into the Fair Trade network, and sees possibilities at the global level for greater convergence between the organic and the Fair Trade movements. In addition to Fair Trade links between producers in the developing world and consumers in the developed world, Jaffee *et al.* (2004) describe recent cases built on Fair Trade principles that operate exclusively between developing countries or exclusively between developed countries.

Initiatives defining and addressing social justice in the organic sector

Many in the organic sector are disappointed with what may be seen as the reduction of the movement's core values into technical packages of practices and prescriptions as to how to farm without chemicals. Stakeholders from a variety of backgrounds concerned with social justice in organic and sustainable agriculture convened at the IFOAM Conference in Victoria, Canada, in August 2002 to address key social justice issues and strategise on moving ahead with a social agenda. Through the Victoria meeting, a social justice survey was developed and disbursed with the intention of mapping the landscape of social justice within sustainable agriculture, seek out opportunities for collaboration and strengthen social justice in sustainable agriculture (Mattson *et al.* 2003). Some of the themes addressed in the survey were:

- general information social accountability;
- social standards and standard setting;
- using standards and verification of standards;
- formal and informal verification systems;
- use of Internal Control Systems;
- formal certification systems;
- social certification and organic certification systems;
- trading relationships;
- trade unions and workers associations;
- capacity building, market development and advocacy;
- research; and
- building a social justice community.

While the survey was ambitious, the response was disappointing with only 38 respondents. However, the social justice forum continued to seek innovative means to network internationally and address social justice at a second meeting in Bangkok in November 2003 (Mattson *et al.* 2003). The Bangkok meeting revealed several gaps in organic and sustainable agriculture standards, among which were the following:

- mechanisms needed for implementation of social justice standards
- no means for farmer price-setting outside market forces
- no fair trade mechanisms in developed countries
- limited capacity among farmers to set standards
- no bottom-up strategies in place for evolving standards
- no definition of child labour within the reality of the farmers
- lack of food security mechanisms for small farmers
- lack of standards for buyers – community/rights and responsibilities/pricing
- lack of recognition for good practices among family/traditional farmers
- assessing whether standards undercut traditional market models
- no discussion of wild harvest products

- no development element
- undocumented workers must be more comprehensively addressed
- better training for social justice needed (e.g. auditor training for social skills)
- no reference made to price setting and subcontractor/operator relationships
- land tenure of indigenous people needs to be addressed
- lack of technical assistance for compliance to producers
- IBS do not address farmer's contracts with buyers
- standards address gender discrimination, but are not explicit about cultural values
- uncertified organic or 'de facto' organic is not addressed in standards
- regulations needed for the negotiation of fair contracts, and
- farmers need access to government programs.

These issues capture the constellation of concerns that are part of the 'social agenda' of the organic movement. Different organisations and individuals are working on different aspects of these concerns and issues in many different ways. The Rural Advancement Foundation International (RAFI) and IFOAM are among them, and their efforts are outlined in the following paragraphs.

RAFI has developed a comprehensive set of social stewardship standards (Henderson *et al.* 2003), with the intent of reincorporating social justice in sustainable agriculture and to address the gaps of other standards and growing concerns of many in the organic sector. The standards are divided into the following sections: farmer rights and buyer responsibilities; buyer rights and farmer responsibilities; indigenous people's rights; farm workers' rights; interns and apprentices. It is uncertain as to whether another label will emerge from these efforts or whether instead the promoters will continue to work with other standard-setting organisations to improve the standards that are already in place.

IFOAM, as the membership-based international voice of the organic sector, has participated in the social justice meetings both in Victoria and in Bangkok, as well as supporting the development and implementation of the survey described above. In addition, IFOAM has undertaken several key initiatives to address the social agenda within the organic sector, including the development of a code of conduct for traders, participation in the Social Accountability in Sustainable Agriculture (SASA) Project, coordination of three years of meetings to address smallholder certification, ongoing communication and collaboration with partners in fair trade, the development of the Organic Traders Charter and so on.

The SASA Project definition of social responsibility issues areas are well recognised as key social justice concerns internationally (SASA 2005). Key issues addressed in the project include:

- general information social accountability;
- freedom of association and right to collective bargaining;
- working hours;
- seasonal workers, contracts and undocumented workers;
- child labour;
- health and safety;
- wages/compensation;
- discrimination;
- basic treatment and disciplinary practices; and
- forced labour.

Although the breadth of social issues and the many conceptualisations of social responsibility in the organic world are outlined earlier in this chapter, the SASA issues listed above are the main components of social responsibility considered further.

Table 14.1 Three perspectives encountered in different social science discourses (after Röling 2004)

Perspective	Government-driven	Market-driven	Community-driven
Rural policy practice (Rob Schrauwen pers. comm., 2005)	Regulating	Compensating	Stimulating
Rationalities (Habermas 1984)	Instrumental	Strategic	Communicative
Bases for individual behaviour change (Kelman 1969)	Compliance	Identification	Internalisation
Preferred ways of arranging human affairs (Hood 1998[A])	Hierarchy	Individualism	Egalitarianism
Organisational coordination mechanisms (Powell 1994)	Hierarchy	Market	Network
Causes of 'wealth of nations' (Bowles and Gintis 2002)	Resources (such as power or access to natural resources)	Invisible hand of market forces	Social capital, trust, community
Institutionalisation (Giddens 1984)	Domination, legitimation	Liberalisation, persuasion	Signification, communication

[A] Reference from the original table: Hood's work is based on Mary Douglas' cultural theory. Mary Douglas discerns a fourth dimension, fatalism, where the sense of belonging to a group is weak, but the domination by rules is strong.

A framework for approaching social responsibility in organic agriculture

This Chapter draws on the work of Niels Röling (2004) (Table 14.1). The three 'ways of getting things done' (Röling 2004) are modified to illustrate the current and envisioned options for social responsibility within organic agriculture. Röling distinguishes several change perspectives that arise in the social sciences, drawing out similarities in the approaches. The first perspective emphasises hierarchy and (government) authority, and employs an instrumental approach that includes compliance to regulations. The second perspective puts emphasis on on market forces, economic incentives and compensation, and employs a rational choice approach with strategic underpinnings. The third perspective relies more on learning, stimulating change, internalising concepts and building social capital and action among equals.

The three dimensions discussed in this Chapter are represented in Figure 14.2: learning, collaboration and regulation. The three dimensions are complementary but distinctive, relying on diverse coordination mechanisms, motives and motivations. Learning is a stimulating approach and regulation provides a framework, while collaboration entails communication with other stakeholders (organisations), recognising available expertise and building relation-

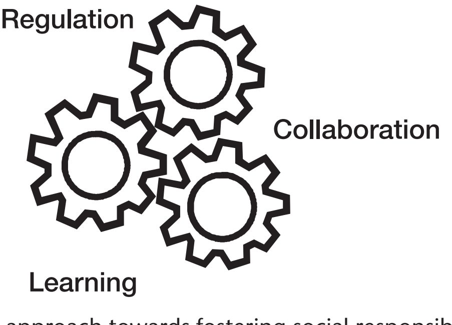

Figure 14.2 An integrative approach towards fostering social responsibility in the organic sector.

ships that benefit the many people engaged. In creating and revising regulations, and when collaborating, learning will inevitably take place among those invited or encouraged to participate. Although the nature and kind of learning taking place can vary, not all stakeholders are always invited. The three approaches are most fruitful when working together in a dynamic way with differences in emphasis depending on the context in which social responsibility is developed. Regulation is seen both as an outcome and an input for (further) learning, while regulation, or rather the process leading to regulation, is also seen as a learning process.

Regulation

Regulation is an instrumental approach depending on a hierarchy of standards, legal regulations, accreditation systems and international guidelines. This approach to social responsibility depends on compliance to social standards set by stakeholders, some within the organic sector, others beyond it such as national laws and the International Labor Organization (ILO). Compliance to widely (internationally) recognised social standards is key to the success of this coordination mechanism. The strength of a regulatory approach is that it is binding, more universal (within a given frame of reference, e.g. a nation), is third-party verified, and it causes social responsibility and social justice to become entrenched in the system. Regulation is already a reality in the organic sector (see *Chapter 9*) and as such, the regulatory framework is outlined in the following subsection. The use of regulations and standards to set parameters and delimit the 'playing field' is indeed valuable.

Current regulatory framework

As the organic sector developed from multistranded, diverse and geographically and culturally distinct movements internationally, in order to assure integrity and retain value for the practices undertaken, ideals have formalised, being articulated as principles, standards, private certification and later as regulations/legislation and international guidelines or standards. The *Demeter* label, first used in 1924, marked the beginning of this non-linear development process (Rundgren 2002). There are about 360 private certification bodies internationally, many with their own standards for people certifying to US, European and Japanese regulations to allow access to those markets (IFOAM 2006). As of December 2001, 56 countries were at different stages of organic regulatory development, 32 with fully implemented regulations (Commins and Kung Wai 2003). The IBS were first published in 1980 and have been revised and voted on every two years (every three years as of 2002) by IFOAM members. IFOAM is working to harmonise both private standards, encouraging mutual recognition among accredited certification bodies (ACBs), and national regulations, to facilitate international trade in organic products. In addition, *Codex Alimentarius*, a joint FAO/WHO intergovernmental body established in 1972, adopted organic guidelines in 1999 and livestock standards in 2001. These private and public definitions of 'organic' set the parameters that govern producers and processors (see Chapter 9).

Compared to production aspects, the human side of organic farming has had less attention in regulatory developments. While social responsibility was a central tenet to many organic movements, it has been sidelined somewhat as the movements consolidated into a rapidly growing and diversifying sector. That said, IBS include a short chapter (8) on social justice. These 'standards for standards' apply to all ACBs accredited with IFOAM's International Organic Accreditation Service (IOAS). ACBs accredited by the IOAS will be inspected during their verification visit as to how they are implementing these social standards. The following excerpt (Box 14.2) reflects the IBS chapter on social justice (IFOAM 2002).

These social standards are basic compared to the more comprehensive standards of other social certification and standard-setting organisations such as FairTrade Labelling Organizations International (FLO), Social Accountability International (SAI), Sustainable Agriculture

Box 14.2 IFOAM Basic Standards, chapter 8 on social justice (from IFOAM 2002)

General Principle

Social justice and social rights are an integral part of organic agriculture and processing.

Standards shall require that:

8.1 Operators shall have a policy on justice. Operators who hire fewer than ten (10) persons for labour and those who operate under a state system that enforces social laws may not be required to have such a policy.

8.2 In cases where production is based on violation of basic human rights and clear cases of social injustice, that product cannot be declared as organic.

8.3 Standards shall require that operators not use forced or involuntary labour.

8.4 Employees and contractors of organic operations have the freedom to associate, the right to organise and to bargain collectively.

8.5 Operators shall provide their employees equal opportunity and treatment, and shall not act in a discriminatory way.

8.6 Children employed by organic operators shall be provided with educational opportunities.

Network of the Rainforest Alliance (SAN), and the ILO. All IOAS-accredited certification bodies are expected to develop their own social standards based on these broad IFOAM standards for standards. Some private organic standards (IOAS accredited or not) already incorporate social standards into their certification. Often producer associations or cooperatives in developing countries are subject to social certification via fair trade in addition to their organic certification (SASA 2005).

Collaboration

Collaboration as discussed here refers to the engagement of multiple stakeholders with each other in the organic sector covering the entire supply chain to better address social justice issues. In Table 14.1, the middle column tends to refer to economic and market approaches. Collaboration is included because in addition to being an approach to (social) learning (see Box 14.3), collaboration is also very strategic and has potential cost-cutting and other economic benefits. In this way collaboration can be regarded as a 'rational choice' approach towards social responsibility.

At least two kinds of collaboration can be distinguished: collaboration among social and environmental certification organisations, and collaboration throughout the supply chain. The former refers to those in the organic sector working with experts in social certification. In this example of collaboration, the intent is not to develop comprehensive social criteria, but rather that the organic sector works with other certification systems that specialise in social issues. The second kind of collaboration refers to coordination throughout the supply chain and as such, is closely linked to the first. In order to ensure that social standards are upheld along the supply chain, coordination is required. An example is the complex organic cotton supply chain that involves among others: producers, ginners, spinners, dyers, exporters, cut/make/trim operators, designers and retailers. Each step holds different ecological and social challenges and demands different skills to adequately address the risks.

Collaboration with organisations more experienced in social certification is a wise and vibrant endeavour for IFOAM. IFOAM, via the International Social and Environmental Accreditation and Labelling (ISEAL) Alliance, has a platform to generate and learn from such

Box 14.3 Mango certification in Burkina Faso (from SASA 2003)

A small producers cooperative in Burkina Faso faces many challenges in achieving Fair Trade and organic certification, accessing socially and ecologically just markets and getting its produce (mangoes) to markets in Europe. The cooperative is spread out over many villages with each farmer working on small parcels of land (about 0.5-2 ha), with mango sales being just one part of their livelihood, though the degree of reliance on mango sales varies from one village to the next. Challenges include: farmer illiteracy exacerbating the need for good documentation, lack of resources for extension and inadequate regional knowledge on certification and group organisation to draw from, timing the fruit pick-ups to coincide with optimal ripeness (ripe, but not over-ripe), refrigeration for transport, and transportation to the port via a third country. These factors are among those demanding attention. In addition, the group seeks both fair trade and organic certification. Each system requires documentation and annual audits/ inspections to verify compliance.

In order to streamline the certification needs, local certifiers (FLO and Eco-Cert) are examining each other's systems to highlight overlaps and where the other certification has higher demands (e.g. FLO has stronger social criteria – the organic certifier can accept FLO's assessment as adequate to meet organic social criteria; and the organic certification has stronger environmental criteria, which are accepted as sufficient for FLO's environmental criteria). By coordinating in this way (including the development of a joint audit template) the inspectors will decrease the time, resource and reporting requirements demanded of the cooperative, while at the same time ensuring the integrity of each system. These kinds of synergistic relationships are being experimented with in order to lessen the burden on small producers and to make more efficient audits possible.

synergistic relationships. However, while representing the organic sector, IFOAM is not the only participant: certification bodies, researchers, producers, consumers and other stakeholders are also challenged to collaborate and make links between ecological justice (which the organic sector does well and has experience in) and social justice.

Learning and social responsibility

There is neither a single outlook as to what social responsibility entails nor a clear pathway marking how it can be achieved in the organic sector. As such, there are different ways to respond to the challenge. One response, a regulatory approach, (see *A framework for approaching social responsibility in organic agriculture*) would be to look for the core meaning and components of social responsibility in organic agriculture that are agreed upon (by some) and prescribed (to others) on a global scale. Discussion then would focus on questions to decide who should determine this core, how an agreed upon core can then be best transferred/communicated so that it is taken up by others and how compliance to standards and guidelines for practice derived from this core can be monitored throughout the entire supply chain. Through negotiation and consensus seeking, experts and (other) stakeholders can arrive at mutually suitable methods and processes for operationalisating social responsibility that can be implemented and enforced on a global scale. Indeed, this has been the approach in developing IFOAM Basic Standards (including chapter 8 on social justice), as well as the broadly recog-

Table 14.2 Emancipatory versus instrumental learning

	Instrumental	Emancipatory
Nature of knowledge	Static, finished (scientifically) agreed upon, universal	Dynamic, under construction, contested, contextual
Process of learning	Transmission, instruction	Transformation, co-creation
Role of learner	Consumer/user of knowledge	Producer/user of knowledge
Role of initiator	Instructor	Facilitator
Origin of learning goals	Pre- and expert determined from the outside	Self-determined from within
Object of learning	Tailor made for specific target groups	Multiple stakeholders in an integrative setting

nised social issues that are taken up by leading social certification organisations (see *Initiatives defining and addressing social justice in the organic sector*). This response is widely practiced.

Another response to the many perspectives on social responsibility regarding organic agriculture is to acknowledge that working towards social responsibility involves questions regarding values, ethics, justice and equity. Pathways towards social responsibility are unlikely to develop without friction, controversy and conflict. This view emphasises that we live in pluralistic societies, characterised by multiple participants with divergent interests, values, perspectives and constructions of reality. Furthermore, working towards social responsibility demands more than universally applicable recipes for social responsibility. Governments cannot rely on the exclusive use of legislation (Table 14.1) to enforce social responsibility. Most countries have basic laws regarding wages, working hours and child labour among others, but this does not necessarily mean they are adhered to. Standard-setting bodies cannot depend only on economic instruments (e.g. premium prices) to stimulate the whole supply chain to act in a socially responsible manner. Genuine social responsibility develops from within and is anchored in values and a deep conviction of what is considered ‘right’ and ‘just’ within a given subculture. The question then becomes more complex as to how can internationally recognised standards integrate with divergent local values (and *vice versa*). International standards, although they are more flexible than laws, are less dynamic than local standards.

Innovation and change in land use, production, processing and consumption can be seen as a result of the learning of individuals and groups active in the agrifood chain (see Figure 14.1 as to the relationship between society and the organic sector). Likewise, learning can generate innovation, change and development of social responsibility in (organic) agriculture. There are many ways to conceptualise the relationship between learning and social responsibility, but for this Chapter we address two possibilities: instrumental learning and emancipatory or social learning. The main differences between instrumental and emancipatory learning lie in: the nature of knowledge, the process of learning, the role of the various stakeholders in learning, the origin of the goals that are being pursued and the object of learning (Table 14.2).

When exploring social responsibility by using this dichotomy, again two pictures emerge: learning *for* social responsibility (instrumental) and learning *towards* social responsibility (emancipatory).

Learning for social responsibility

The ‘for’ suggests that there is something known and agreed upon when it comes to social responsibility in organic farming. Indeed, there are legal and regulatory frameworks within which organic agriculture operates. As well as IFOAM’s social standards and private certification schemes, the Charter for Organic Trade and the ILO guidelines among others address elements of social responsibility. Experts, policy-makers and special interest groups have influenced these frameworks, schemes and codes, and seek to get producers, processors and traders to adopt them. Through information, extension, persuasion, rewards and punishment, relevant participants can be moved to comply with the standards, norms and guidelines that have been set. This type of learning can be categorised as instrumental (Table 14.2). It relies heavily on the regulations and standards already in place.

Learning towards social responsibility

'Towards' suggests that while there are a constellation of ideas as to what social responsibility entails, the lack of consensus about the implications of an exact meaning in variable contexts prevents global prescriptions. Although there is certainly agreement about basic components of social responsibility and social justice, more nuanced understandings and applications need to be constructed contextually in an integrative process involving all stakeholders.

Some would argue that consensus about an ill-defined issue such as social responsibility is undesirable from a radical democracy perspective. Radical democracy offers a way of thinking about difference, as opposed to seeking consensus. Democracy, from this perspective, depends on differences, dissonance, conflict and antagonism so that deliberation is radically indeterminate (Goodman and Saltman 2002). In this view, the conflicts that emerge in the exploration of social responsibility are prerequisites rather than barriers to reaching more sustainable solutions. According to Chantal Mouffe (Mouffe 2002, p. 73):

> We should acknowledge and valorise the diversity of ways in which the 'democratic game' can be played, instead of trying to reduce this diversity to a uniform model of citizenship. This would mean fostering a plurality of forms of being a democratic citizen and creating the institutions that would make it possible to follow the democratic rules in a plurality of ways.

Social responsibility can be seen as a process that negotiates language meanings and cultural understandings between equal parties with equal access to the negotiating table (Goodman and Saltman 2002). Where such equality is lacking, measures need to be taken to overcome inequalities to create more optimal conditions for social learning. As such, social responsibility can be viewed both as an evolving product and an engaging process. Social responsibility as a social learning *process* deserves more attention as do the more accepted concepts of social responsibility as an expert *pre*determined transferable *product* (i.e. as set by a law or standard).

If the premise is accepted that there is neither a single outlook on what social responsibility entails nor a process to achieve it, then one might also accept that determining the meaning of social responsibility is a process that involves all kinds of stakeholders in many contexts, people who may not agree with one another. There are different levels of self-determination, responsibility, power and autonomy people can exercise while engaged in such issues or disputes. In dealing with conflicts about how to organise, consume and produce in socially responsible ways throughout the organic supply chain, learning does not take place in a vacuum but rather in rich social contexts with innumerable vantage points, interests, values, power positions, beliefs, existential needs and inequities. The amount of flexibility that individuals have for making their own choices, developing possibilities to act and for taking responsibility for their thoughts and actions, varies (Wals and Jickling 2002, Wals and Heymann 2004).

A continuum can be used to indicate the different levels of self-determination, self-responsibility and autonomy people can exercise within social responsibility-oriented learning processes that are directly related to the individual's room to manoeuvre. Another continuum can be distinguished, one expressing the degree of openness and the extent to which outcomes and

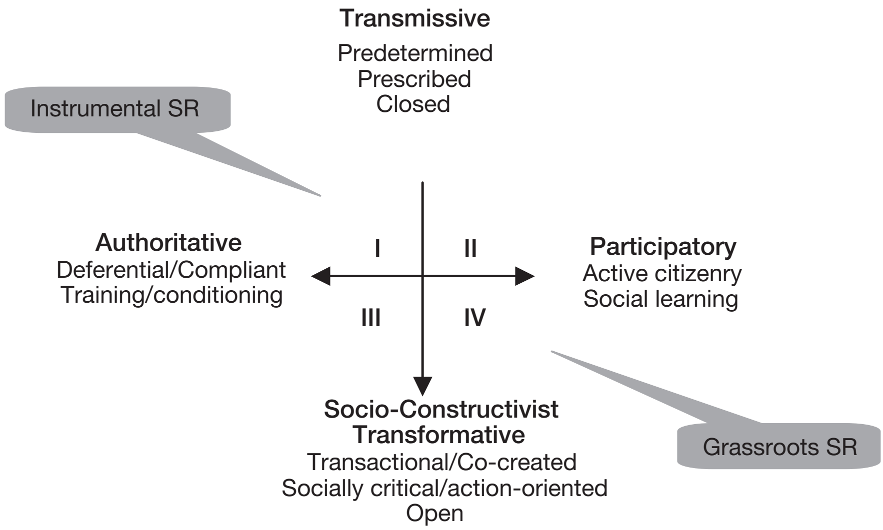

Figure 14.3 Emancipatory and instrumental perspectives on fostering social responsibility in the organic sector (after Wals and Jickling 2002).

processes are prescribed to citizens. The resulting force field (Figure 14.3) shows four different conceptualisations of social responsibility and the role of citizens in moving towards social responsibility (Wals and Jickling 2002).

The upper left quadrant of the force field can be named 'big brother' or instrumental social responsibility: social responsibility that has been authoritatively determined and defined by experts and prescribed to relatively obedient and passive citizens (see Orwell 1949). The lower right quadrant represents grassroots social responsibility, characterised by the active and critical involvement of competent and action-oriented citizens with high levels of self-determination in finding pathways towards 'social responsibility as agreed upon by all', and high levels of empowerment and self-actualisation. Whether the resulting society is sustainable or would be viewed as 'socially responsible' from the outside is questionable, but people might be happier with their situation (as compared to the first scenario), at least for a while.

The other two cells represent forms of social responsibility characterised by a limited openness and/or involvement. This can be seen, for instance, when groups are encouraged to actively participate in the implementation of a guideline for social responsibility that has been predetermined without their involvement. Limited or even false participation is often the result.

Figure 14.3 as presented here is perhaps normative with a bias towards openness and participatory democracy. The bias is somewhat contrived when considering, for example, the role of expertise. In the upper left quadrant there is a tendency to downplay ordinary peoples' voices and to stress expert knowledge ('the experts know what's right, the others know nothing'), while in the lower right quadrant there is a tendency to downplay expert knowledge and to stress the ordinary peoples' voices ('leave it to the people and their own local knowledge, without outside interference'). A more fruitful approach may be to consider each quadrant as a potential starting point towards social responsibility and to recognise that all quadrants have something valuable to offer. This becomes immediately clear when we return to Table 14.1 and Figure 14.2, which emphasise the utilisation of multiple perspectives depending on the context and the stage of development. Figure 14.3 can be reflected upon as a heuristic device that can support the analysis of positions adopted and alternative future directions.

Conflict in social responsibility

In considering the levels of self-determination illustrated in Figure 14.3, different types of potential conflicts can be envisioned to emerge as stakeholders endeavour to move towards social responsibility. The two extremes are the big brother instrumental approach and the grassroots emancipatory approach towards social responsibility and citizen involvement. In big brother social responsibility, conflict is avoided or kept under the table internally, by using 'objective', rationally determined standards or norms. An abundance of social standards, guidelines and regulations to achieve this can be cited (e.g. ILO, Fair Trade, SA8000, IFOAM IBS chapter 8, national labour laws). After determination of the norms and standards, a range of instruments are used for implementation or enforcement: laws, legislation, regulation, reward and punishment schemes, (mandatory) training and instruction or financial incentives. These instruments leave people little choice but to adapt the expected behaviour , if they aspire. Conflict might emerge internally when setting the standards and deciding on how to implement them, but once agreed upon, any doubts about the standards are masked as much as possible. This gives producers and consumers confidence in the reliability of the scheme. When rules are broken, standards are either not met or are met superficially, or critiqued by certain groups, conflict does emerge eventually among those affected by the rules, regulations and standards.

In grassroots social responsibility different perspectives, kinds of expertise, values and interests converge in a consensus-seeking process in which conflict is inevitable. Cultivating conflict and using conflict as a force for conceptual change and creative problem solving is a prerequisite for arriving at solutions that people can identify with and act upon. Ownership of solutions is thus engendered. Social responsibility in this approach is rooted in local contexts taking on many forms and shapes as contexts change geographically and over time. Social responsibility develops on the edges of carefully facilitated and sometimes mediated encounters between different interests, values and world views. In an ideal social learning process, all participants involved jointly arrive at a temporary vision of social responsibility which they share and identify with. In the last analysis, social responsibility in this context comes more from within, rather than from outside. There may not be consensus about everything but there might be a renewed sense of community and interdependency, and even respect for differences or respectful dissension (Lijmbach *et al*. 2002) and radical democracy (Goodman and Saltman 2002). This quadrant has its flip side. There will always be differences in knowledge bases, access to resources, including networks and therefore inequities which lead to conflict and even demand more instrumental guidance and/or outside expertise, if only to help overcome these inequities. Likewise, big brother learning has its positive side where it can make transparent and transferable the values/standards necessary for certification.

Inter and intrastakeholder learning

> 'Bettering the condition of our farm workers shouldn't fall solely on the farmer', says Muller, a 25-year veteran of organic farming. Everyone in the food chain needs to adopt a sense of fairness and responsibility for the well-being of farm labourers. It needs to be a partnership through the whole agriculture system, with wholesalers and consumers paying fair prices that then assure that farm workers are adequately compensated in an equitable way. The equation of greater social responsibility needs to be integrated though the whole food system (Kupfer 2004).

When viewing the role of learning with respect to social responsibility, the levels of learning need to be identified. Three such levels can be distinguished: micro, meso and macro. The individual learner (i.e. the farmer) who learns from experience or from others, particularly

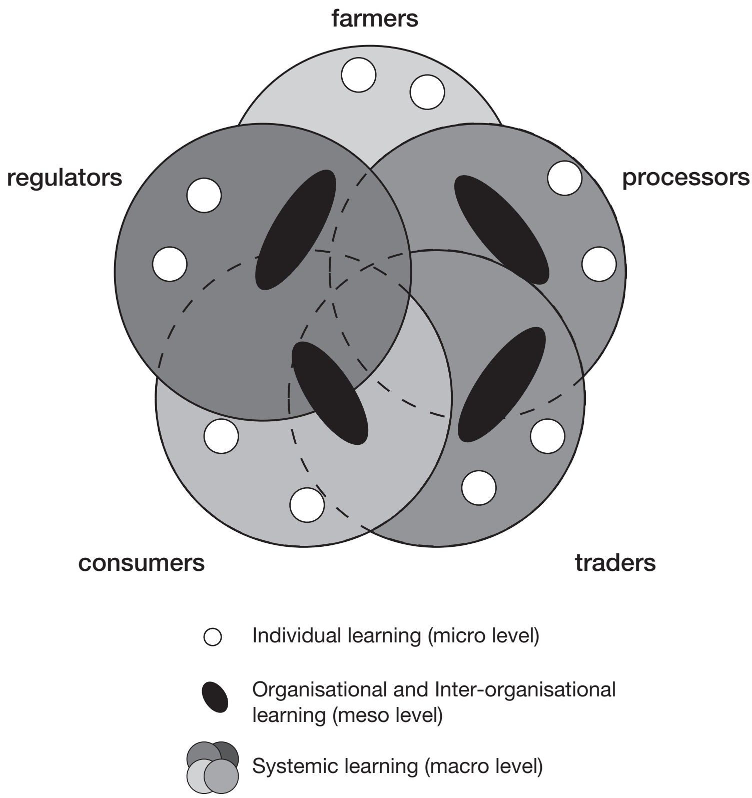

Figure 14.4 Levels of learning among stakeholders in the organic sector. Learning levels shown are micro (individual learning), meso (organisational and interorganisational learning) and macro (systemic learning).

from other farmers, is placed at the micro level (Figure 14.4). Micro level learning can be both informal and more formally organised (e.g. in farmer field-schools, farmer groups for co-learning, farmer study groups). At the meso level (Box 14.4) are communities of learners at local and regional levels or at a particular point in the supply chain (i.e. learning within cooperatives, farmer associations, trade unions, processing facilities).

Learning at the meso level requires that multiple stakeholders meet somewhere or somehow. Here too, informal and more formally organised learning can take place. Examples of more informal social learning at the meso level include farmers' markets where consumers and producers interact and learn from the interaction (Box 14.4), or microfinancing schemes where policy makers, intermediate institutions and poor farmers interact around loan schemes (Pretty 2002) or where standard-setting organisations work jointly on a project to address shared issues. The meso level may also be relevant within a particular circle (i.e. producer associations, trader forums, unions, consumer associations, platforms of ACBs, standard-setting organisations) and can become a first step towards more systemic learning (e.g. subsystem learning). The SASA project is an example of systemic learning (Box 14.5).

At the macro level there is systemic learning that takes place within an entire sector, involving all stakeholders in the supply chain and certification hierarchy. A key assumption underlying this type of learning is that the whole system is more than the sum of the participants and their relationships making up the system, and that systemic innovation can take place only with the full participation of all contributing to the system.

Box 14.4 United Farm Workers of America – an example of meso-systemic learning (UFW 2001)

The United Farm Workers of America, AFL-CIO and community allies are working on a new initiative with nationally renowned consultants, major retailers, and local growers to develop a formula that will ensure a greater return to the farm gate, guaranteeing fair prices, justice, and dignity to Washington State farmers and farm workers.

The initiative is guided by the principles that farmers should earn a fair return for their investment and farm workers deserve just wages and decent work conditions. Contractual agreements between the United Farm Workers, willing growers and retailers will guarantee that the grower and farm workers get a fair share of the consumer dollar.

A collectively bargained contract between the grower and the workers will ensure safe and just conditions for the workers. However, consumer support, commitment, and demand is key! We need to demonstrate to retailers and growers that consumers, like you, will buy apples – that mean fairness to growers and farm workers! We believe that a significant number of consumers care about what you eat, how it is produced, and whether those who produce and harvest your food can sustain themselves. Show Washington State farm workers that you care!

When looking at social responsibility issues, many require a systems approach to arrive at sustainable solutions. Macro level learning is complex and hard to organise, and examples of multilevel, systemic, chain-oriented learning (MLSCL) are rare, certainly within the context of organic farming. Most multinational companies such as McDonalds, Unilever and Nike, considered to be operating successfully at a global scale, owe their success to creating tightly knit chains that respond quickly to changes in the global economy. Although the added value of these chain-oriented companies tends to be limited to economic value and the distribution

Box 14.5 Social Accountability in Sustainable Agriculture (SASA) Project as an example of systemic learning (SASA 2005)

The SASA Project was a two-year initiative (February 2002–April 2004) of the ISEAL Alliance undertaken by four platform members: IFOAM, SAI, SAN and FLO. The project was coordinated by Sasha Courville at the Australian National University in Canberra.

Nine audit exercises on nine different production systems provided shared learning experiences in a variety of contexts that fed steering committee discussions and learning. Pilot audits included: bananas in Costa Rica, mixed farms in Italy, orange juice in Brazil, rice in Thailand, flowers in Colombia, mangoes in Burkina Faso, strawberries in the USA, coffee in Costa Rica, and cotton in Uganda. Participants in the audits included representatives from each of the participating organisations at many levels: producers, internal inspectors and extension workers, certification bodies, standard-setting bodies and researchers.

Outcomes of the project included documents with recommendations on the following topics:

- standards;
- collaboration opportunities among participating organisations; and
- Internal Control Systems for small producers in developing countries.

Steering Committee members are presented the SASA recommendations to their Boards.

of the added value can hardly be called equitable, these chains seem to be very effective. There are some examples of MLSCL-learning in watershed or catchment management schemes that involve multistakeholder social learning. Examples of MLSCL within the organic farming context that seek to create added value not only economically, but also ecologically and socially within the entire chain, tend to be regionally oriented, although there are also some transnational examples.

The development of social responsibility can be seen as a dialectic between intrinsic (personal values) and extrinsic motivations (external pressures). This dialectic occurs at all three levels.

A three-pronged approach to social responsibility

Although so far this Chapter has focused predominantly on the learning approach towards social responsibility, we advocate a mix of coordination mechanisms to stimulate, regulate and provide incentives for social responsibility throughout the supply chain. By providing stimulating learning and cooperation among organisations that promote social responsibility, and by solidifying that what is learnt in agreed-upon and broadly supported rules and regulation, a three-pronged approach serves the sector well. Although learning is a 'soft' tool that allows room for errors, local variation, differing conceptualisations and the generation of a sense of ownership and internalisation of values, regulations delimit the playing field, also for those unable to participate in the learning and collaboration processes described in this Chapter. Box 14.6 illustrates how the three coordination mechanisms can work together providing a basis for change and the development of stronger social responsibility in the organic sector.

The ICS combine the three coordination mechanisms put forth in this Chapter as potential approaches towards social responsibility, at the farmer level, or more specifically, at the developing country small farmer cooperative level. By drawing in and developing the learning element of internal control systems, producer organisation ICSs can become learning organisations with systemic learning as a key component of their operational process.

The ICS is an example of a meeting point between grassroots and big brother learning. At the grassroots level, farmers learn about technical aspects of organic production, learn to organise themselves (in a cooperative in some cases) and provide documentation of their farming practices. In addition, a structure is in place through which community initiatives can be pursued (e.g. a Thai rice cooperative wherein self-sufficiency objectives were met via the ICS structure). At the big brother level, the 'rules' are set by the certification body; however, the producer organisation must adapt and internalise the standards by creating a manual that expresses the group's goals, localising them to reflect local challenges and risks.

Regulations and standards are necessary parameters, especially when they emerge from a multistakeholder social learning process, and when they are not carved in stone but seen as flexible outcomes in need of constant revision. They are important in defining what is internationally accepted in terms of social justice. Many issues, including workers' rights, child labour and freedom of association demand clear international guidelines as organic food chains transcend local realities. Informing those who did not participate in their creation is a more instrumental process, although giving them meaning in a local context is not. Likewise, other issues (see *Introduction* and *Social responsibility in the organic context*) may be more amenable to local variations and interpretations. For these issues, a more emancipatory learning approach appears more appropriate. Collaboration and social learning at multiple levels throughout the supply chain between organic and social standard-setting bodies is key to addressing and improving this neglected piece of the organic movement.

Box 14.6 Internal Control Systems – combining coordination mechanisms for social responsibility (R. Pyburn, PhD research on ICS as part of the SASA Project)

An Internal Control System (ICS) is a certification mechanism that allows smallholders in developing countries to access organic markets through producer group certification. First developed in Latin America in the 1980s as a development tool, ICSs allow producers to come together as a cooperative or an association for marketing and the certification of production. IFOAM estimates that there are over 350 producers groups with 150,000 members internationally (March 2003 Position paper) and that about 60% of organic produce sold in Europe comes from developing countries.

Organic ICSs have required elements that include:

- internal monitoring system;
- external verification that focuses on the system with samples based on risk assessments of individual producer farms;
- internal system for extension and capacity building; and
- joint marketing.

The ICS that are certified to IOAS-accredited certification body standards are compelled (as of the 2002 IBS revision) to comply with chapter 8 on social justice (see *Box 14.2*) as well as the rest of the IBS. In addition, many ICSs are part of producer cooperatives that also have fair trade certification. As such, additional social justice and development standards are in place – the regulatory and collaboration dimensions. The learning element of ICSs is perhaps the most dynamic and interesting. Extension is an integral and essential aspect of ICSs – and is predominantly used for technical issues. However, ICSs, once in place are often a framework for other kinds of development and learning (e.g. parallel systems – HIV/AIDS education in Uganda via EPOPA Projects, local community economics in Thailand).

Conclusions

Different kinds of learning about and towards social responsibility and at multiple levels are essential ingredients to improving social responsibility within the organic sector. Formation of coalitions, political alliances and innovative networks, as well as creative use of confrontation and conflict, would all make for many forms and levels of learning and lead to progress in the social responsibility arena. Collaborations like these within the sector need to be crystallised in agreed-upon and somewhat flexible regulations and economic incentives that support the sector and promote further learning.

To reiterate our conclusions and recommendations, social responsibility in organic agriculture needs to include:

1 Standards and/or regulations on baseline social issues (see e.g. ILO, SAI, fair trade, IBS Chapter 8), created and supported by multiple stakeholders in the organic food chain.
2 Collaboration between organic standard-setters and certifiers with other social standard-setters and certifiers (e.g. FLO, SAI, SAN, ILO, trade unions) to better address social responsibility.
3 Learning on social responsibility needs to be embedded at all levels within the organic supply chain (producers, processors, exporters, wholesalers, retailers) and certification hierarchy (standard-setting organisations, certification bodies, farmer organisations, farmers). Ideally the standards and regulations listed under a hierarchy are – temporary

and always subject to revision – outcomes of such learning as opposed to the outcome of an instrumental process dominated by just a few powerful interests.

Fortunately, there has been much recent progress towards these goals via the innovative SASA Project and other ISEAL Alliance platform initiatives, IFOAM's *Charter on Organic Trade* and *Code of Conduct for Organic Trade*, and fair trade/organic certification collaboration in the field. The levels and kinds of learning presented are meant to provide opportunities and (organic) food for thought on how to stimulate the sector with respect to social responsibility and nourish the endogenous, local spirit of the organic 'movement'. More research needs to be done to understand the interface and interplay between the three proposed mechanisms, if only to get a better grip on how to coordinate the three mechanisms and to create the proposed synergy between the three. The coordinating mechanisms and responsibilities within the entire chain need to become clearer in order to foster social responsibility throughout the organic sector that is grounded in social learning and is supported by a dynamic framework of standards and regulations.

References

ALDI Australia 2006. *Frequently Asked Questions about ALDI. Do You Sell Organic Products?* ALDI Australia, Minchinbury. <http://australia.aldi.com/faq_01/start.html#anchor4>. Accessed 16/1/06.

Allen, P. and Kovach, M. 2000. The capitalist composition of organic: the potential of markets in fulfilling the promise of organic agriculture. *Agriculture and Human Values* 17: 221–232.

Allen, P. 1999. Reweaving the food security safety net: mediating entitlement and entrepreneurship. *Agriculture and Human Values* 16: 117–129.

Allen, P., FitzSimmons, M., Goodman, .M and Warner, K. 2003. Shifting plates in the agrifood landscape: the tectonics of alternative agri-food initiatives in California. *Journal of Rural Studies* 19: 61–75.

Alrøe, H.F. and Kristensen, E.S. (2004). Investigating organic agriculture in a global perspective. In: *Third Global Conference on Environmental Justice and Global Citizenship, Copenhagen, February 2004*.

Anonymous 2003. *Biofach Trade Fair Spotlights Organic Products*. German Embassy, Washington DC. <http://www.germany-info.org/relaunch/info/publications/week/2003/030214/economy3.html>. Accessed 21/8/05.

Buck, D., Getz, C. and Guthman, J. 1997. From farm to table: the organic vegetable commodity chain of Northern California. *Sociologia Ruralis* 37 (1): 3–20.

Campbell, H. and Liepens, R. 2001. Naming organics: understanding organic standards in New Zealand as a discursive field. *Sociologia Ruralis* 41(1): 21–39.

Commins, K. and Kung Wai, O. 2003. Status of national organic regulations. In: Westermayer, C. and Geier, B. (eds) 2003. *The Organic Guarantee System – the Need and Strategy for Harmonization and Equivalence*. IFOAM, Tholey-Theley, Germany. pp. 16–23.

Dabbert, S., Haring, A.M and Zanoli. R. 2004. *Organic Farming – Policies and Prospects*. Zed Books, London.

DARCOF 2000. *Principles of Organic Farming*. Danish Research Centre for Organic Farming, Foulum.

Goewie, E. 2002. *Certification and Inspection as an Instrument for Quality Management by Organic Farmers*. Wageningen University, Wageningen.

Goodman, D. 2000. Organic and conventional agriculture: materializing discourse and agro-ecological managerialism. *Agriculture and Human Values* 17: 215–219.

Goodman, D. 2004. Rural Europe redux? Reflections on alternative agro-food networks and paradigm change. *Sociologia Ruralis* 44: 3–16.

Goodman, R.T. and Saltman, K.J. 2002. *Strange Love or How we Learn to Stop Worrying and Love the Market*. Rowan and Littlefield, Oxford.

Guthman, J. 2000. Raising organic: an agro-ecological assessment of grower practises in California. *Agriculture and Human Values* 17: 257–266.

Guthman, J. 2004. *Agrarian Dreams: The Paradox of Organic Farming in California*. University of California Press, Berkeley.

Hall, A. and Mogyorody, V. 2001. Organic farmers in Ontario: an examination of the conventionalization argument. *Sociologia Ruralis* 41(4): 400–422.

Hansen, L. 2004. Hvordan star det til med arbejdsmiljøet på de økologiske landbrug? *Forskningsnytt om økologisk landbruk i Norden* 1: 19–21.

Henderson, E., Mandelbaum, R., Mendieta, O.and Sligh, M. 2003. *Towards Social Justice and Economic Equity in the Food System – A Call for Social Stewardship Standards in Sustainable and Organic Agriculture*. Rural Advancement Foundation International, Pittsboro.

IFOAM 2002. *IFOAM Basic Standards for Organic Production and Processing*. IFOAM, Tholey-Theley, Germany.

IFOAM 2006. *Organic Directory Online*. International Federation of Organic Agriculture Movments, Bonn. <http://www.ifoam.org/organic_world/directory/index.html>. Accessed 16/1/06.

IFOAM Executive Board 2003. *IFOAM's Position on Small Holder Group Certification for Organic Production and Processing*. IFOAM, Tholey-Theley, Germany.

Jaffee, D., Kloppenburg Jr, J.R and Monroy, M.B. 2004. Bringing the 'moral charge' home: Fair Trade within the North and within the South. *Rural Sociology* 69: 169–196.

Kaltoft P. 1999. Values about nature in organic farming practice and knowledge. *Sociologia Ruralis* 39(1): 39–53.

Kaltoft, P. 2001. Organic farming in the late modernity: at the frontier of modernity or opposing modernity. *Sociologia Ruralis* 41(1): 146–158.

Klonsky, K. 2000. Forces impacting the production of organic foods. *Agriculture and Human Values* 17: 233–243.

Kupfer, D. 2004. *Striving for Social Sustainability in Agriculture*. Rodale Institute, Kutztown. <http://www.newfarm.org/features/0804/worker/index.shtml>. Accessed 31/8/05.

Lijmbach, S., van Koppen, K., Margadant, M. and Wals, A.E.J. 2002. 'Your nature is not mine!' Developing pluralism in the classroom. *Environmental Education Research* 8(2): 121–135.

Mattson E., Paulsen, O., Mandelbaum, R., Panyunkul, V., Allen, P., Courville, S., Mesh, M., Blake, F., Nickoleit, G., Pyburn, R., Sligh, M. and Kalus, D. 2003. *Social Justice Survey. Social Justice and Social Certification in Sustainable Agriculture. Evaluation of Results Social Justice Workshop. Organic Trade Conference Bangkok, Thailand. 4 November 2003*. RAFI–USA, Pittsboro. <http://www.rafiusa.org/programs/SocialJusticeSurveyResults.pdf>. Accessed 21/8/05.

Michelsen, J. 2001. Recent development and political acceptance of organic farming in Europe. *Sociologia Ruralis* 41: 3–20.

Mouffe, C. 2000. *The Democratic Paradox*. Verso, London.

Oppermann, R. 2003. Arbeits- und Berufsverhältnisse im ökologischen Landbau aus soziologischer Sicht. In: Rahmann, G. and Nieberg, H. (eds) *Ressortforschung für den ökologischen Landbau 2002 FAL*. Bundesforschungsanstalt für Landwirtschaft, Braunschweig. *Sonderheft* 259: 74–78.

Orwell, G. 1949. *Nineteen Eighty-Four*. Harcourt Brace Jovanovich, USA.

Pretty, J. 2002. *Agri-culture: Reconnecting People, Land and Nature*. Earthscan, London.

Pyburn, R. 2003. SASA project smallholder ICS workshop report. *Biofach Organic Trade Fair 2003*. February 15, 2003. Nuremberg, Germany.

Raynolds, L.T. 2000. Re-embedding global agriculture: the international organic and fair trade movements. *Agriculture and Human Values* 17: 297–309.

Raynolds, L.T. 2004. The globalization of organic agro-food networks. *World Development* 32: 725–743.

Röling, N. 2004. Teaching interactive approaches to natural resource management. In: Corcoran, P.B. and Wals, A.E.J (eds) *Higher Education and the Challenge of Sustainability: Problematics, Promise and Practice*. Kluwer Academic Press, Dordrecht. pp. 181–198.

Rundgren, G. 2002. History of organic certification and regulation. In: Rundgren, G. and Lockeretz, W. (eds) *IFOAM Conference on Organic Guarantee Systems: International Harmonisation and Equivalence in Organic Agriculture, Nuremburg, Germany*. IFOAM, Tholey-Theley, Germany. pp. 5–7.

SASA Project 2003. *Burkina Faso Organic/Fair Trade Mango Researcher Notes and Audit Report*. Social Accountability in Sustainable Agriculture, ISEAL Alliance, Kaslo.

SASA 2005. *SASA Project Sucessfully Completed*. Social Accountability in Sustainable Agriculture, ISEAL Alliance, Kaslo. <http://www.isealalliance.org/sasa>. Accessed 21/8/05.

Tovey, H. 1997. Food environmentalism and rural sociology: on the organic movement in Ireland. *Sociologia Ruralis* 37(1): 21–37.

UFW 2001. Fair Trade Apple Campaign. UFW'S Apple Initiative for Fairness. United Farm Workers, Keene. <http://www.ufw.org/apple.htm>. Accessed 16/1/06.

Wals, A.E.J. and Heymann, F.V. 2004. Learning on the edge: exploring the change potential of conflict in social learning for sustainable living. In: Wenden, A. (ed.) *Educating for a Culture of Social and Ecological Peace*. SUNY Press, New York. pp. 123–145.

Wals, A.E.J. and Jickling, B. 2002. 'Sustainability' in Higher Education from doublethink and newspeak to critical thinking and meaningful learning. *Higher Education Policy* 15: 121–131.

Wier, M., Andersen, L.M. and Millock, K. 2004. Information provision, consumer perceptions and values – the case of organic foods. In: Russell, C. and Krarup, S. (eds) *Environment, Information and Consumer Behaviour*. Edward Elgar Publishing, London. pp. 161–178.

Special topic 5

Voice from the other side: a Ghanaian view on organics

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Introduction

This special topic was written to explain and emphasise a radical change in agricultural development in Africa. It shows that organic farming and an organic process of development helps Northern Ghanaian farmers better than conventional development projects.

The changes that have to be made include the following:

- Any change in (agricultural) development should start from the existing (agricultural) practices, yield levels, knowledge and attitude and not from the promises, potentials or perspectives of a new, to be introduced, technology (see *The African backbone is agriculture* and *The traditional production level*).
- Development projects should change from a technical orientation of development into a mix of technical, social and cultural orientation because Africans have a multidisciplinary or integrative view on life, sustainability and on development (see *Extension is technically oriented* and *The organic approach: sustainability as a subject of extension and participation as an extension method*). As one farmer said: 'Soil erosion is soul erosion'.
- Development projects should change from top-down processes towards bottom-up processes (see *Extension method is top down*).
- Development approaches should change from a disciplinary subject through a top-down extension method into a integrated topic through a participatory development process (see *The organic approach: sustainability as a subject of extension and participation as an extension method* and *Participatory extension methods*.

Organic farming is more than a way of farming; it is also a way if living and developing. Organic farming links an integrative way of farming with a participatory method of development to reach sustainability. In experiences recounted in *Voice from Northern Ghana: organic farming and participatory extension*, practical examples and achievements from Northern Ghana are presented. *The challenge: 'stop soul erosion'* is a plea for more projects that combine organic farming methods with participatory extension methods instead of repeating top-down approaches to introduce new techniques such as genetically modified crops. The potentials of organic techniques and bottom-up development processes have been underestimated and should be tried out far more.

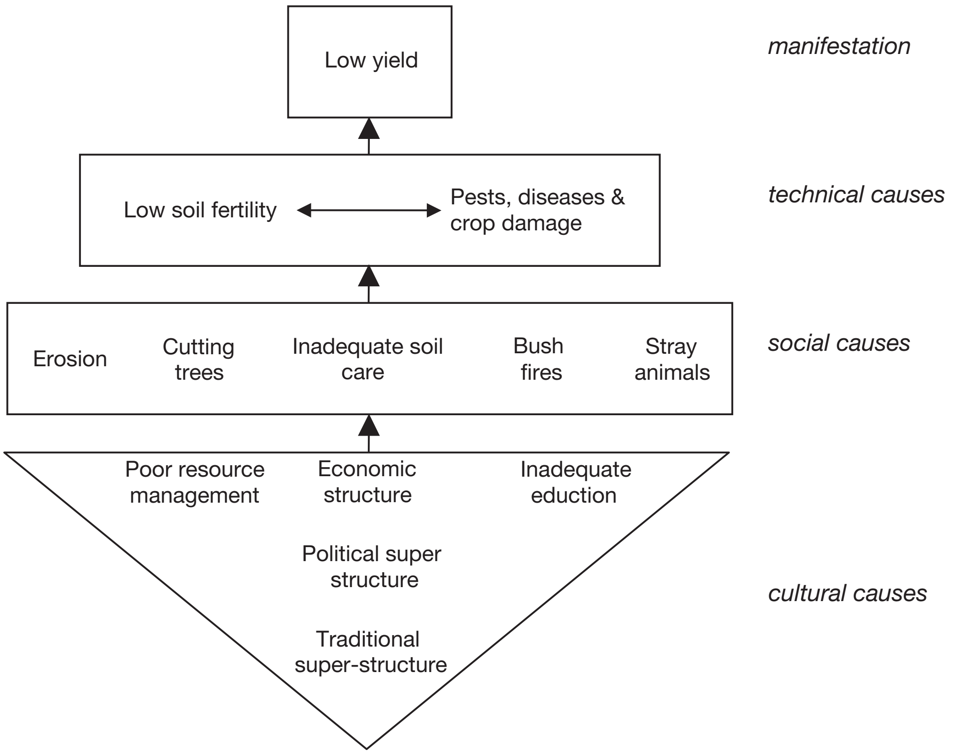

Figure 1 Soil fertility in the Northern Ghanaian context.

The African backbone is agriculture

The backbone of African societies is agriculture. Most African farmers first produce to feed their own families, and second produce for the national and world market. In general, soils are poor and fertility is easily lost by bad practices. In Ghana, for example, soil fertility is always threatened by human activities like tree felling, bushfires and stray animals (Figure 1).

In Ghna it is very clear: agriculture is the carrier of society. If agriculture is not developing, then other development (e.g. education, health, literacy, food security) will be very difficult. In Northern Ghana, about 30% to 40% of children are malnourished (GDHS 1998). These children grow into adults with a limited capacity to contribute to the labour force and enact change, which will impede development. Although more than only food security is needed to prevent malnutrition, agriculture is the starting point for development.

The traditional production level

Grain production yields, especially maize, the most important staple crop in Northern Ghana, range from 1000 to 4500 kg ha^{-1} (Iddi 1996), depending on the rate of inputs. When farmers do not use inputs, and this includes most farming households, production levels are determined by natural processes like deposition by the desert wind called the Harmatan, nitrogen fixing by leguminous weeds, erosion from higher located fields and the use of animal manure (Table 1).

Maize contains 9% protein, and protein contains 16% nitrogen (N). A maize yield of 1 tonne containing 14.4 kg N, means an N efficiency of 70%. This is already quite high. When erosion occurs or manure is not applied, yields will reduce immediately. Where natural inputs

Table 1 Nitrogen balance of traditional maize farming in Northern Ghana

Nitrogen input (kg ha^{-1} y^{-1})		**Nitrogen output**	
Harmatan dust	5	1000 kg maize	14.4 kg N kg ha^{-1} y^{-1}
Leguminous weeds	10		
Manure	3	Nitrogen efficiency =	(N output / N input) × 100%
Erosion	2		
Total	20		

are the main inputs, yield levels will be around 500 kg ha^{-1}. This means that whenever a farmer uses inputs, yield level will increase tremendously. The most important question is: by which extension method can we convince farmers to use locally available inputs like animal manure, compost and green manures?

Extension is technically oriented

Existing agricultural policy and extension techniques are not successful in increasing soil fertility. The recommendations of Lynn (1937) to improve soil fertility and food security in 1937 (Box 1) are the same as the focus of Ministry of Food and Agriculture in 2005 (GV2020 2005).

The recommendations of Lynn (1937) and the Ministry of Food and Agriculture in 2005 (GV2020 2005) have never been promoted in a successful way. The main reason for this is that the focus of extension was too oriented on the use of chemical fertilisers, pesticides and hybrid varieties. Green revolution techniques in Ghana did not result in increasing soil fertility levels and thus, yields. Besides that, chemical fertilisers can never be the solution since the prices of fertilisers and pesticides over the last 15 years have been on such a level that farmers cannot afford them. Farmers also observe the negative impact of chemical fertilisers on soil structure and soil life (Box 2).

The 'training and visit' method of extension that accompanied the green revolution is, as such, not a bad system of extension, partly because there is room to include social and cultural issues. But whenever this system uses only a technical approach, promoting green revolution farming without considering the ecological, social and cultural context of rural families, the developmental effect is very limited. Or even worse, it makes farmers dependent on the fertiliser

Box 1 Recommendations by C.W. Lynn (1937)

Mr Lynn was a British agricultural superintendent studying 'indigenous agriculture'. In his publication *Agriculture in North Mamprusi* he mentioned the following suggestions to improve farming systems:

- growth of a greater diversity of crops
- the introduction of crop rotation
- using cow manure to fertilise the soil
- cultivation of green manures
- use crop residues as litter instead of burning them
- plant crops in ridges made on the contour
- grow more rice in waterlogged areas
- improve varieties of seeds

Yield levels of maize, sorghum, millet and rice at that time were about 600 kg ha^{-1}.

Box 2 Experiences of Nwodua women

Nwodua is a small village 5 km east of Tamale in Northern Ghana. In a village meeting about compost and chemical fertilisers women mentioned:

- when we use chemical fertilisers worms disappear
- the soil becomes very hard when we use chemical fertilisers
- after two years of using fertilisers the soil is dead, nothing will grow!
- compost keeps the soil moist
- compost makes the soil soft and easier to handle
- compost works for years while chemical fertilisers are finished after one year.

The women were very sure about their observations.

industry and when farmers do not supply their soils with organic matter to catch and hold the nutrients, the soil degrades and erodes to such a level that the land can no longer be used for farming. The technical approach to develop agriculture has failed in Northern Ghana.

Extension method is top down

The present focus of the Ministry of Food and Agriculture (GV2020 2005) and other agricultural non-government organisations (NGOs) in Northern Ghana is still the same as the recommendations given by Mr Lynn in 1937. Sixty-seven years of agricultural extension and still the same problems! How is that possible? In many discussions with farmers, an additional problem was found with top-down extension methods. Many of the extension workers, researchers and politicians see rural people as backward and do not see the value of rural knowledge, views and attitudes. Top-down extension methods do not support agricultural development in this situation.

The organic approach: sustainability as a subject of extension and participation as an extension method

Many experts in development emphasise that development should start from traditional knowledge, attitudes and practices and should fit into the local way of reflecting, thinking and doing. To introduce any new techniques without an idea or feasibility study on how these techniques could fit in the social set up of the community and how they fit in the worldview of rural people, may easily lead to disappointments or as scientists say to ‘low adoption rates’. Boxes 3, 4 and 5 reflect the integrated view of rural people. This complex mix or complete integration of material, social and cultural meaning of trees, animals, machines and so on should be the starting point of a development process.

A disciplinary solution towards a multidisciplinary problem will not work. Besides this single technical focus on development, the top-down approach of introducing new techniques does not fit into the traditional way of communication and development. Traditionally a new technique is, after introduction into a Ghanaian community, discussed at the community level in a meeting where groups (e.g. elders, women, the youth), opinion leaders (e.g. the teacher, local politician, traditional priest, pastor) and people from outside (e.g. government extension worker, university researcher) put forward their points of view. The task of the chief is to come to a decision that is supported by all participants of the meeting. This process takes time, sometimes even years. But the village meeting is normally the place where important decisions are discussed and made. Too many development projects in Ghana do not pay enough attention to this traditional way of community development.

Box 3 View on trees

In a naive mood I once asked the Nwodua chief: 'What is a tree?'

He gave me an answer that has changed my life view completely: 'A tree gives us food, timber and shade to meet. A tree is also the place where our ancestors find their home! Without trees we cannot live'.

In scientific terms trees have three main functions:

1 a material/technical function – provides, for example, food, medicines, timber and brooms;
2 a social function – the sun can knock you down in Northern Ghana; the shade of a large tree is as much needed as food and water; in every African village meetings take place under the crown of a large tree; most important decisions in a village are made under a tree;
3 a cultural function – trees provide homes for spirits and ancestors; the ancestors are the caretakers of the norms and values of rural people; they are consulted whenever a decision has to be taken – which society can live without norms and values?

The chief taught me a lesson: everything in life has a technical, a social and a cultural dimension, so also agricultural extension has to be organised in this context.

Box 4 The maize sheller

In the chief's palace in Mbanayili, a village 10 km east of Tamale, Northern Ghana, I met the chief, his elders, the youth and even some women. The topic was a explanation and demonstration of the maize sheller (a conical shaped tube with four knives on the inside. To remove the maize kernels, the cob is turned in the tube). After an explanation of the costs and how it is made by a local blacksmith I took a maize cob and turned it in the maize sheller. The maize kernels jumped out of the sheller and the audience was surprised by the speed of shelling and the ease of handling the tool. I explained proudly that this simple tool prevents wounded thumbs and that the tool is cheap so farmers can buy easily five shellers and shell together all the maize in one day. Story telling, which is normally done during shelling when the whole family is gathered around the maize harvest, is still possible! The people clapped their hands and expressions of surprise filled the room. I mentioned immediately that the tool was costing only 5000 cedis (around 1 dollar).

Suddenly the chief asked for attention through his spokesman. The spokesman just stated that this technique is not appropriate. Reasons were not given and the meeting was over. The chief left the room, leaving behind his people and myself with many questions. I tried to investigate the reasons for the rejection of this tool by the chief.

It took me a few months to find an answer by consulting researchers, pastors, the director of the cultural centre and other experts. The reason for the rejection was as follows. The chief considered himself as the custodian of traditional values. That is his task in the village. Maize shelled by a tool is not appropriate to use in sacrifices to the ancestors. Maize should be shelled by hand. For selling purposes mechanically shelled maize is allowed but for sacrificing purposes mechanisation was not allowed. This tool went against tradition! This does not mean that traditions are a block for development. According to the experts, it is a matter of proper introduction of the tool. I came to the village, demonstrated the tool and thought that after the demonstration that I would be able to sell some and that the people were happy about this simple improvement. But I should have followed another procedure. The demonstration was okay, but after that I should have asked if the people, and especially the ancestors of the people in the village, were willing to accept this tool to make work easier. The chief could have consulted the ancestors in his own way and after that he would inform the village about the ancestors' answer.

I followed the wrong procedure. I did not respect their way of introducing new technologies.

Box 5 A farmer's definition of sustainability (Professor Saa Dittoh, pers. comm. 1998)

In a village I asked a farming community: 'What does sustainability mean to you, what makes you "able to sustain" life?'

The groups explained easily:

- enough food
- enough cash
- rich natural environment, especially a fertile soil
- peace, trust, harmony and unity in the community
- a place for worshipping.

Again translating these issues into scientific terms: sustainability is a complex of food security, cash security, environmental security, social security and last, but not least, cultural security. One can not go without the other.

An integrated view on sustainability (Box 5) is very useful and will help development projects for rural people in their types of activities. A technical approach used on its own has only a limited effect, as does the cultural approach alone (e.g. as attempted by some churches). A balanced mix of approaches or a multidisciplinary focus seems to be the best.

So when the subject of extension has been determined, namely sustainable development, the method of extension has to be found. Top-down extension methods have failed. But how to get a bottom up or a right mix between top-down and bottom-up approaches? In Northern Ghana the participatory technology development approach, as a mixture of bottom-up and top-down approaches, has shown fascinating results in pilot projects and shows great potential to boost sustainable development in rural areas.

Organic agriculture tries consciously to combine a multidisciplinary way of development with a participatory method of extension (see *Box 6* for a definition of organic agriculture).

Participatory extension methods

Much has been written on participatory extension techniques. In principle it is a continuous process of assessing a situation, analysing it and taking action to improve the situation (Box 7).

Voice from Northern Ghana: organic farming and participatory extension

Organic agriculture and participatory extension techniques belong with each other. Experiences to emphasise this mutual beneficial relationship are listed below. The experiences were collected during several years of fieldwork in Northern Ghana with farmers and development workers.

Box 6 Organic agriculture as defined by the International Federation of Organic Movements (IFOAM 2000)

Organic agriculture includes all agricultural systems that promote environmentally, socially and economically sound production of food and fibre. These systems take local soil fertility as a key to successful production. By respecting the natural capacity of plants, animals and the landscape, it aims to optimise quality in all aspects of agriculture and the environment. Organic agriculture dramatically reduces external inputs by refraining from chemical fertiliser and pesticides. Instead it allows the powerful laws of nature to increase both agricultural yields and disease resistance. Organic agriculture adheres to globally accepted principles, which are implemented within the local socioeconomic, climatic and cultural settings. As a logical consequence, IFOAM stresses and supports the development of self-supporting systems on local and regional levels.

This definition is fully in line with the farmer's definition of sustainability (see *Box 5*) and the view on trees by the chief of Nwodua (see *Box 3*).

Organic agricultural development starts with a more efficient use of local resources

A participatory extension approach stimulates farmers to use local resources. Local resources such as mulching, composting, basket composting or zai-composting, dynamic kraaling whereby the kraal in which animals stay at night moves over the arable land, zero-grazing units where animal are fed day and night, trees as windbreak, agroforestry-systems, green manuring with *Mucuna* or *Crotalaria* spp., crop rotation, contour ploughing, manure protection, use of neem leaves, ridge boxing, nursing and transplanting early millet, use of white acacia trees that drop their fertile leaves in the rainy season, animal traction, use of cashew trees as climbing stakes for yams, and the use of the maize sheller (Box 4) are all experiments conducted by male

Box 7 The principle steps in a participatory extension process (Reijntjes *et al.* 1992)

Participatory extension methods are cyclic and ongoing processes. They should be owned by the target groups but can be initialised and guided by outsiders.

Step 1 Meet the community, group of farmers and get to know each other. Building trust is important.

Step 2 Identify the key problem in agriculture or any other topic to which the extension method is focusing. The Participatory Research Action method may be helpful to find the key problem.

Step 3 List possible solution for the key problem; excursions, expert consultation and visiting research stations could be used to list options; farmers know also solutions themselves – by the end there should be a basket full of options.

Step 4 Let the target group select one or two options to try out. Try to find indicators to measure the impact of the tried options.

Step 5 Make a plan to implement the chosen options.

Step 6 Share the results with everybody who wants to know.

Step 7 Evaluate the results: did it solve the problem? If yes, tackle the next key problem and continue with step 3. If no, try another solution.

and female farmers in Northern Ghana in participatory development projects. It is easy to make this list of local resources longer. The point is that through a well-guided extension process, farmers are encouraged to use these local resources. Also, in Northern Ghana, farmers are brainwashed and think that farming is only possible with chemicals. Local resources are often seen as too laborious, too difficult to get or lacking clear effects. An enlightened farmer summarised it as follows: soil erosion is possible because of soul erosion. Through a participatory extension process farmers realise that with local resources many problems can be solved. Organic farming increases the awareness of available natural resources.

When the participatory process is well guided it increases the confidence and independence of farmers tremendously

Farmers reported that yields following compost application increased up to 4000 kg ha^{-1} of maize and more importantly, that crops are less prone to damage from dry spells because of higher soil organic matter content. Some farmers even experiment with the combination of compost and fertiliser. They achieve yields of up to 5000 kg ha^{-1}. One particular farmer planted trees around his 8 hectare farm and allowed 2.8 hectares to develop into forest. The leaves of the fence and the 2.8 hectare forest kept the soil very fertile. This was a self-developed system. Another farmer used fodder trees and thorny plants to make a kraal for animals. The fodder trees provided food and shade for the animals and the thorns prevented damage to the trees. A third farmer allowed a local green manure (*Occidentalis* spp.) to grow between yam mounds. In mounds where yam-plants did not grow well, the leaves of green manure were dug in, resulting in larger yams.

When farmers are successful in solving problems on their own, their confidence increases. A participatory process increases the ownership feeling of the problem and of the solution. The potentials of this kind of development process are highly underestimated by development workers.

Northern Ghanaians live in communities and in large social networks

The individual is nothing without a group of people. Individual development is difficult. There are many mechanisms that prevent individuals from developing. Development should, in principle, benefit the whole community; therefore, Zasilari Ecological Farms Project (ZEFP 2006), as with many other successful development projects, works with groups. ZEFP asks community members to forms groups, often consisting of people who are already in the same social network. After training in group dynamics, group organisation and the basics of money literacy, ZEFP guides the groups through a participatory extension approach. This group work, especially when there are successes, improves trust and harmony among the members considerably. Trust and harmony are some of the basics of sustainable development (Box 5). Working in groups gives farmers identity and status and strengthens the social network.

Traditional societies are not static

Changes are accepted when the right procedures are followed. If local group or community leaders do not accept change, individuals are not motivated to use new technologies. Acceptance largely depends on the way of introducing the change. Traditional procedures in which local gods and ancestors are consulted about the acceptance of new technologies still exist in Northern Ghana. In many development projects, such cultural acceptance procedures are overlooked. Often, changes are assessed on their economic benefits. Certainly, the traditional leaders will also assess the new technology or the economic benefit, but will also assess their ‘cultural security’. In the case of the maize sheller (Box 4), the chief was worried that during maize shelling, in which the whole family is involved, the older family members tell traditional stories. These stories are very important in transferring norms, values, family and community background from the old to the young generation. Besides that mechanically shelled maize could not be sacrificed, the chief was also worried that an efficient way of maize shelling would reduce the time available to educate the younger generation in the culture of the community. These processes should not be underestimated. A participatory approach gives more room for the participants to include these cultural aspects into the development process than a top-down extension approach. However, it may take time. In a community in the Builsa district in Northern Ghana, it took two farming seasons before the local leaders accepted composting as a promising method to improve soil fertility. The traditional leaders consulted their ancestors and because, as they said, 'composting will provide more good food to the ancestors', they accepted and promoted this new technology. In another community, the people strongly believed that burning the fields around their compounds was needed to, as they described it, 'prevent the chief from dying'. It took village members and development workers two years of talking to convince the traditional leaders to implement an experiment. The compromise was that instead of putting the whole community farm to fire, only a few fields should be burned. After the blessings of the ancestors they implemented the experiment. The chief did not die and the yields on the compound farms increased and the whole community was happy.

These experiences show that organic farming is more than just a way of farming. Organic farming is an example of sustainable development owned and organised by farmers themselves. Organic farming deals with a development in which all technical, social and cultural aspects of life are considered. To start this development, assistance from development organisations is needed. These organisations should have a participatory approach and the attitude that sustainable development should start from local resources and techniques, local knowledge and local attitudes and traditions.

The challenge: 'stop soul erosion'

The challenge for organic development organisations and rural people is to convince more development organisations, and especially governments and large donor-organisations, to experiment with organic farming in combination with participatory extension techniques. The present trend to use biotechnology and to use top-down extension methods to introduce genetically modified crops such as cotton, soybeans and maize should be highly questioned. The potentials of organic techniques and bottom-up development processes have been underestimated and deserve far more consideration.

References

GDHS [Ghana Demographic Health Survey] 1998. *Ghana Statistical Service, Demographic and Health Surveys*. Macro International, Maryland.

Iddi, G.S. 1996. Towards a sustainable agricultural development with particular reference to the Northern Region. In: *University for Development Studies* (ed.) *University for Development Studies Conference on 'Partnership for Sustainable Development'*. May 1996. University for Development Studies, Tamale, Ghana.

IFOAM. 2002. *Organic Agriculture and Food Security*. International Federation of Organic Agriculture Movements, Tholey-Theley, Germany.

Lynn, C.W. 1937. *Agriculture in North Mamprusi. Bulletin No. 34*. Department of Agriculture Gold Coast, Accra.

GV2020 [Ghana-Vision 2020] 2005. *The First Step: 1996–2000 Presidential Report to Parliament on Co-ordinated Programme of Economic and Social Development Policies*. Assembly Press, Accra.

Reijntjes, C., Haverkort, B., Waters-Bayer, A. 1992. *Farming for the Future: an Introduction to Low-External-Input and Sustainable Farming*. Macmillan, London.

ZEFP [Zasilari Ecological Farms Project] 2006. *Profile of Zasilari Ecological Farms Project (ZEFP)*. ZEFP, Walewale. <http://www.zefpatghana.com>. Accessed 18/1/06.

Chapter 15

Research to support the development of organic food and farming

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Introduction

Agriculture and organic agriculture in particular are developing rapidly, not only as a result of technological change but also to changes in agricultural policy and public expectation. Research allows new knowledge to be developed and is thus vital for the future of organic agriculture. The question, 'What is the purpose of research on organic farming? Is it to increase yield and productivity, to compare it with other forms of agriculture, or to quantify its environmental and social impact, minimise the adverse effects and maximise the benefits and so on? The answer is of course, that research has a role in all of these and many other aspects of developing the organic food chain. The precise purpose of the research is usually defined by the funding body, and may differ with whether the funding body is from the public or private sector. In this Chapter, development of organic research is examined briefly through both the public and private sectors and then some of the issues that surround research on organic agriculture in terms of approaches and appropriate methodologies is explored. The extent to which organic and conventional agriculture require different research and different approaches to research is explored.

History and status of organic research

Niggli and Willer (2001) define four stages in the development of organic farming research:

1. pioneer farmers and scientists;
2. pioneer private research institutes;
3. organic farming chairs at universities; and
4. organic farming projects and institutes at state research institutions.

Stage 1 is characterised by the comparisons of organic and conventional farming systems at Haughley, Suffolk, England initiated by Eve Balfour (Balfour 1943). Although many scientists today would not recognise this as a scientific experiment, there is still some useful information to be gleaned from those early pioneers (Blakemore 2000). The private institutes that emerged through the 20th century (Table 15.1) generally have been driven by outstanding individuals or

Table 15.1 Private institutes

Country	Organisation	Year established
Germany	Institute for Biodynamic Agriculture	1950
Switzerland	Forschungsinstitut für biologischen Landbau	1974
Netherlands	Louis Bolk Institute	1976
United States of America	Rodale Institute	1976 (founded in 1947)
Austria	Ludwig Boltzmann Institute	1980
United Kingdom	Elm Farm Research Station Henry Doubleday Research Association	1982 1984
Sweden	Biodynamic Research Institute	1986

groups of individuals with a strong personal commitment to organic or biodynamic agriculture. Many of those same individuals were responsible for the 1st International Scientific Conference of the International Federation of Organic Agriculture Movements (IFOAM) held in 1977, and described by Niggli (2002) as the debut of organic farming research. Some of the private organisations, such as the Louis Bolk Institute, were founded to allow researchers to pursue research that was not accepted by conventional scientific organisations, such as homeopathic studies (Van Mansfeld and Amons 1975). However, it was really during the 1980s that public funding for organic agricultural research started to become available. During the same period, positions and departments of ecological and organic agriculture began to appear in universities in Europe. The first chairs of organic or alternative agriculture in Europe were established at the University of Kassel at Witzenhausen, Germany, and Wageningen University in the Netherlands in 1981; the first Chair in Biodynamic Agriculture was established at Kassel in 2005.

During the 1980s in the United States of America (USA) there was one United States Department of Agriculture (USDA) post assigned to work with the Rodale Institute, Pennsylvania (Parr 2003), although there were other linkages between farmers, university staff and USDA staff during this period (Jawson and Bull 2002). Support for USDA involvement in organic research was only realised in 1998 when the Organic Farming Bill was finally passed by the US Congress. The first faculty position dedicated to organic farming in a Land Grant University was established at Iowa State in 1997 (Delate and DeWitt 2004). The situation has changed rapidly, however, and in September 2003, the USDA announced US$4.5 million in grants for organic agriculture projects (USDA 2004). In Australia, research is funded from levies paid by producers and matched by Commonwealth funding, as well as by state departments of agriculture and universities. Wynen (2003) estimated that in 2001 only around two-thirds of the A$656,200 funding was actually spent on research that directly benefited organic farming.

The USDA funding for organic research is aimed at helping farmers and ranchers to increase the production of high quality products while decreasing costs (USDA 2004). The focus of the research appears to be very much within the farm, and orientated towards production rather than the environment. The five-year R&D Plan for Organic Produce (2001–2006) formulated in Australia by the Rural Industries Research and Development Corporation (RIRDC) covers many aspects of the supply chain both on and off farm, with market development and communication featuring heavily (RIRDC 2005). The *European Action Plan for Organic Food and Farming* was launched in June 2004 (Commission of the European Communities 2004). Action 7 relates specifically to strengthening research on organic agriculture and production methods. One area that is highlighted in the plan is the need for research in the processing sector of the organic food chain. Within the Sixth Framework Programme (2002–2006) of the Commission of the European Communities there is no specific ‘agriculture’ priority but relevant topics are contained within the programs on ‘Food quality and safety’, ‘Sustainable development, global

Table 15.2 Estimated national financial input into organic farming research in 11 European Union countries (ERANET)

The estimate is a minimum based on targeted organic research programs that does not include, for example, professorial appointments in organic agriculture.

	Current[A]	Future[B]
Austria	0.7	1.5
Denmark	8	7
Finland	2	2
France	5.7	5.7
Germany	10	7
Italy	1.5	2
Netherlands	8	8
Norway	3	2
Sweden	5.7	5.9
Switzerland	10	15
United Kingdom	3.2	3.9
Total	57.8	60

[A] Average 2000–04, [B] 2005–10.

change and ecosystems' and 'Strategies for sustainable land management' (Commission of the European Communities 2004). Amounts of funding available in several EU member states are given in Table 15.2. Each member state of the EU also has its own Action Plan, containing guidance on research to be funded at national level. Within the UK, funds have been set aside to encourage industry funding of organic research through the LINK scheme, where government matches industry funding. There is some concern among the UK research community that this may not be an appropriate funding route, given the incompatibility between the need for a systems focus in research on organic farming and the limited availability of industrial funding bodies with an interest in farming systems (Elm Farm Research Centre 2003). The LINK scheme works well where agriculture is driven by inputs rather than ecological systems. There is a similar scheme operating in Canada where companies can become research partners and their funding will be matched by government. Five categories of partner are recognised on the basis of the level of contribution made OACC (2005).

Cropping aspects of organic production have received more attention than livestock aspects until recently; this is reflected in the number of refereed publications (Watson and Atkinson 2002). Lund and Algers (2003) relate the later development of research on animal husbandry to the situation in Europe where the regulations for organic animal husbandry were established only in 1999, eight years after the regulations on crop husbandry (Council Regulations 2092/91 and 1804/99). Biodynamic agriculture has received little funding from public sources, although considerable work has been carried out in some private research institutes. A short description of the development of biodynamic research and institutions in Europe and the USA is given in Koepf (1993). Reports of biodynamic systems in mainstream journals are relatively rare, although there are some notable exceptions such as Reganold *et al.* (1993) and Carpenter-Boggs *et al.* (2000).

Researching organic systems

According to Lockeretz and Anderson (1993), there is a need for rethinking the approaches, processes and institutional structures of agricultural research, because of the range and scale of consequences that agricultural research is expected to address today. There are high political demands on the relevance and proactive perspective of research relative to the changing goals, intentions and values of society and agriculture. These demands are not restricted to agricultural research. They are part of a more general change in the conception of science and its role in society, from that of science as an independent source of objective knowledge to that of science as special learning process within society.

Agriculture is an area undergoing rapid development, both in terms of technological development and the development of alternative production systems, and agricultural research is influential in these developments. In this sense, agricultural science is a 'systemic' science, a science that influences its own subject area (Alrøe and Kristensen 2002). Furthermore, agricultural practice involves both social and ecological systems, and research into these socioecological systems faces the dual challenge of understanding complex agroecosystem interactions and the practices of people in social systems. Agricultural systems research is, therefore, inherently framed in a social context, and necessarily involves questions concerning different interests and values in society as well as different structures of rationality and meaning (Kristensen and Halberg 1997).

There is, therefore, a need to explicitly address how values in the form of intentions and social interests feature in agricultural research. This is in terms of where and how values enter into the research process, and also in terms of what the systemic nature of agricultural research means in relation to the conventional scientific criteria of quality. This need applies generally to agricultural research. Moreover, the role of values is particularly evident with regard to organic farming, because special values and goals are obvious and decisive and because these values are clearly different from the values of mainstream agriculture.

The special values of organic agriculture are summarised and what this obvious and manifest value basis means for organic research, how is to be performed, and how it is to be evaluated is briefly considered. Sound research approaches and appropriate methodologies for organic research are described and the relationship between organic and conventional research is discussed.

Ethics, principles and standards

Organic farming has differentiated itself from conventional agriculture by way of alternative agricultural practices, world views and values. Most notably, the organic movement has explicitly formulated basic principles and standards for organic production and processing. The principles are based on a perception of humans and human society as an integrated part of nature and a holistic conception of health. Understanding the ecological processes that drive productivity and environmental impact through soil biology, vegetation dynamics, pest population dynamics, disease epidemiology and so on, is a key to improved organic systems. This does not imply that they are unimportant in conventional farming. Organic farming does, however, not have access to all the technological means for overcoming natural and ecological insufficiencies and problems (notably artificial pesticides, fertilisers, preventive medicine) that conventional farming has, and it therefore relies on cooperation with natural ecological systems to a greater extent. Values of animal welfare, biodiversity and livelihood are also an integral feature of organic farming. This comprehensive, integrated view of nature and ethics is evident in one of the original key ideas of organic agriculture that 'the health of soil, plant, animal and man is one and indivisible' (Lady Eve Balfour in Woodward *et al*. 1996).

In the existing IFOAM Basic Standards (IFOAM 2002), there are 15 principal aims plus general principles for each area in the standards, and the principles are thus quite complex to overview. There is, however, a process going on within IFOAM to rewrite the principles of organic agriculture. The process is expected to result in a set of basic ethical principles to be decided upon in the General Assembly 2005 in Adelaide. In the draft of May 2005, there are

Box 15.1 IFOAM draft principles of organic agriculture, May 2005

Principle of health
Organic agriculture should sustain and enhance the health of soil, plant, animal and human as one and indivisible.

Principle of ecology
Organic agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.

Principle of fairness
Organic agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.

Principle of care
Organic agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

four principles on health, ecology, fairness and care (POA Task Force 2005) (Box 15.1). From the perspective of research, the formulation of basic ethical principles of organic agriculture have been advocated as a necessary tool for researchers to initiate far-seeing, proactive research that can assist the development of organic agriculture, and the sustainable development of agriculture in general, in a constructive and critical way (Alrøe and Kristensen 2004). The present IFOAM process will hopefully provide a simpler and more consistent source of organic principles for researchers to use as a starting point when planning and performing research on organic agriculture.

Quality criteria for organic research

In the same way that proponents of conventional agriculture have criticised organic farming so too have 'conventional' researchers criticised organic research. In the foreword to Tinker (2000), it is suggested that 'the majority of literature on the subject [of organic farming] was written from a strongly committed point of view'.

This kind of critique can lead the organic research community to reflect on the quality of past organic research, and whether organic research can be of high quality. The answers to these questions depend entirely criteria of quality that are used. Some of the critiques of organic research are based on the presumption that science should be free of values and ideologies, an idea that Thompson (1995) has termed 'ethical reductionism'. The argument is that organic agriculture is inherently ideological, science should operate without reference to ideologies and, therefore, research that operates from the viewpoint of organic ideology and values is not scientific.

But science is neither value free nor independent. Values do and should enter into important phases of the research process such as problem identification, design of methods and experiments, model assumptions and the use of normative concepts (Alrøe and Kristensen 2002). Some concepts that are widely used in agricultural research are clearly value laden. Obvious examples include sustainability, food quality, soil quality, nature quality, animal welfare, rural development and human wellbeing. Such concepts often have different meanings in different groups, discourses and research disciplines. These conceptual differences influence the kinds of technologies and production systems that are investigated and developed, and how the systemic connections of food systems are handled in research. The exposure of the different meanings of such concepts, and the values and ethics embedded in these different meanings, has already been the subject of some attention.

Values have a more direct role in the choice of problem to investigate. There is always a choice of subject matter or research issue in science, though this choice is not always explicitly discussed. This choice depends on the perspective that is used and on what is taken as problematic from this point of view. The choice determines the potential relevance of the research to different groups or to society in general, and it is connected to underlying goals, interests and values. Moreover, 'technical' choices on research objects (as determined in the setup of experiments and surveys), research methods and model assumptions are not independent of values either. Take the example of setting up of farm systems experiments. When such experiments are established, choices include which systems, the specific structure of them, where to make them either similar or different. In a study of dairy systems, are those systems to be 'organic', 'integrated' or 'conventional' and (since none of these are clear cut) what kind of organic, integrated or conventional? Are the stable systems to be based on solid manure or slurry? Are the breeds to be Jersey, Holstein or something else? Are the bull calves to be sold or fattened, as steers or bullocks? These choices on system structure are in many ways related to the intentions and goals behind the research. Once an experiment has been established, these intentions and goals no longer influence the conduct of the experiment. However, when the results are ready, if an organic system with deep bedding and solid manure is compared with a conventional system with slurry, then the choice of systems structure influences the results (e.g. with regard to welfare, nutrient losses, crop yields) (see Lantinga 2001).

Values are important in agricultural science, be it conventional or organic. From this, it follows that the handling of different perspectives and the values and understandings that they harbour is important in relation to the communication and cooperation between researchers engaged in organic and conventional systems, and in cross-disciplinary communication in general. It also follows that objectivity in the sense of value freedom is not an appropriate criterion of scientific quality. There is a need to revise the ideal of objectivity so that it can span the range of criteria that are developed in individual research disciplines across the sciences, and support cross-disciplinary cooperation and communication. The criterion of reflexive objectivity has, therefore, been suggested as a second general quality criterion of agricultural research that complements the criterion of relevance (Alrøe and Kristensen 2002, Schjønning *et al*. 2004) (Box 15.2).

The criterion of reflexive objectivity suggests that research should investigate and describe its own societal, intentional and observational context and work explicitly with the goals and values involved, to facilitate peer criticism and the use and critique by different users and stakeholders. Reflexive objectivity and relevance seem to be important criteria for all agricultural research but not least in organic agriculture because of the important role of values in this form of agriculture. Making the role of values explicit is a way to avoid the two pitfalls of organic research:

1 it lacks real relevance for organic agriculture; and
2 the organic values directly influence the research results.

If one conceives of agricultural science as systemic, recognises the interaction of agricultural research, agriculture and society, and accepts that agricultural research therefore cannot and should not be value free, then such general changes in the perception of agricultural science cannot be implemented by single researchers or research groups alone. The successful implementation of such changes in perceptions will involve all the different institutional struc-

Box 15.2 Key quality criteria for organic research

Relevance	Reflexive objectivity
Establishing the societal and intentional context of the research by way of: 1 participation 2 value inquiry 3 transparency	Communicating the cognitive context of the research results by way of: 1 clarifying values and revealing funding 2 documenting methods 3 ensuring the falsifiability of theories, models and hypotheses 4 establishing the generalisability of the results 5 showing relevant areas of ignorance and uncertainty.

tures of science (e.g. organisational structuring of research, research policy and funding, scientific journals and other media of publication, educational institutions).

Sound research approaches in organic agriculture

From the early days of organic research, holistic approaches were held up to be more appropriate for organic systems than reductionist ones, embracing the integrative philosophy of organic farming (Howard 1943, Woodward 2002b). This has in part led to the idea that the holistic approach to research is the 'holy grail' of organic research. The extent to which this type of research occurs is, however, questionable. Lockeretz (2000) carried out an analysis of organic and conventional research published over ten years in the *American Journal of Alternative Agriculture* and concluded that there was no systematic distinction in the kinds of questions posed or how they were answered between organic and conventional research. However fitting that may be for the history of organic research publication, the aspirations towards more holistic research methods in organic agriculture are worthy of a more comprehensive analysis. A range of barriers against the realisation of holistic aspirations can be found, and a two-pronged approach, which will look at the soundness of research methodologies in the organic context as well as at methodological and institutional barriers, is outlined.

There has been a long-standing and unfruitful opposition between reductionist and holistic science in connection with agricultural and ecological research (see e.g. Lockeretz and Anderson 1993, Thompson 1995, Rowe 1997), which has hampered cross-disciplinary cooperation. From the holistic view, analytic, reductive methods are necessarily reductionist and are therefore bad science because they do not capture the connectedness of complex reality. Furthermore they are (at least in part) to blame for the present agricultural and environmental problems. From the reductionist view, analytic, reductive methods ensure the objectivity of science, and other methods are, therefore, not scientific.

Two comments are pertinent. First, any scientific method will give a 'reduced' view – the world as we see it is not 'the real world'. Hence the term 'holistic' seems to promise more of science than can be fulfilled. Second, since reduction is a powerful approach in science that can contribute significantly to learning, the term 'reductionist', which often has a negative ring, should be used only where a science is unaware of the consequences of reduction or denies that there are any such consequences.

A more comprehensive systemic or wholeness-orientated approach does not imply a dismissal of traditional disciplinary science. But it does imply that the consequences of reduction must be included in the answers that science provides. As argued above, good science exposes and communicates the societal, intentional, and observational context of research, in order to achieve good and valid communication and critique of the results. This communication is also an important precondition for better cooperation between different kinds of science. In this view, the different kinds of research have the same potential for doing good science, and this view of science can, therefore, serve as a better platform for promoting cross-disciplinary research cooperation.

The efforts toward more holistic approaches to research in organic agriculture can be divided into four groups:

1 holistic methods such as picture creation by way of crystallisation;
2 systems research, including long-term crop rotation trials and farm system experiments;
3 participatory approaches that involve stakeholders in research, including on-farm research and action research; and
4 cross-disciplinary research approaches that include 'non-agricultural' disciplines, social sciences and the humanities in a comprehensive systemic research methodology.

Holistic methods

One exception to the rejection of Lockeretz (2000) of there being any difference between organic and conventional research is in the controversial area of food quality from organic production. Debate centres on whether there are qualities of foods, important to health and wellbeing, that are not sufficiently well understood to permit appropriate quantitative measurements to be made (Atkinson *et al.* 2002). Recent discoveries such as the ability of antioxidants to remove or protect against the impact of free radicals (Ramirez-Tortosa *et al.* 2001) suggest that there is still much to learn about the links between food and health. Scientists working on organic production have focused on developing holistic methods that link food quality and production systems, such as crystallisation methods based on the work of Pfeiffer (1975) and others. Such concepts, however, continue to be ridiculed by the conventional science community (e.g. Williams 2002).

These methods are only holistic in a certain, narrow sense that concerns the way food quality is measured in the laboratory. The samples that are measured may come from traditional agricultural trials. Another example of a method that combines rigorous experimental methods with a holistic measure is the experimental study of the influence of organic diets on the health of rats (Lauridsen *et al.* 2005). Many consumers expect organic food to be healthier than conventional, but it is very difficult to test this hypothesis in a scientific way. Other factors also influence human health so that they may hide the effect of organic diets, and it is difficult to generalise from measurements of single components of organic diets to the holistic state of health. However, Lauridsen *et al.* (2005) did show that comprehensive measures of the effects on health can be obtained from a study on rats under standardised experimental conditions, and that in some respects, the rats benefited from eating organically grown food.

Systems research

The sustainability of organic farming in the long term is of major interest to policy makers. Several long-term cropping system trials have been established to investigate this (e.g. Table 15.3, Table 15.4). There is a clear split in research approaches between studies that compare organic and conventional systems (e.g. Mäder *et al.* 2002, and further examples in Table 15.3) and studies that compare different management systems within organic farming, in order to improve the systems (e.g. Olesen *et al.* 1999 and further examples in Table 15.4).

Considerable research effort and funding has been spent comparing and contrasting organic and other types of farming systems. The trials listed in Table 15.3 mostly address rotations for horticulture or agriculture. Few studies compare systems of perennial cropping, one exception is the Washington State apple production systems trial (Reganold *et al.* 2001). Within Table 15.3, treatments have been classified into organic, biodynamic, low input or integrated and conventional on the basis of the author's descriptions. One difficulty in interpreting these experiments, and indeed making comparisons between them, is the lack of definition of the terms of low input and integrated farming. Furthermore, there is huge variation in farming systems across relatively small geographical regions (Trewavas 2004). There is also a lack of information available in the public domain on actual practices on organic farms, although this information may be available within certification organisations. Such comparisons can provide useful information when the purpose of the study is clearly defined (Spedding 1975) and the basis of the comparison is fair. Defining starting points, boundaries and time scale are important in this respect. Lampkin (1994) points out that the fundamental issue is the comparison of systems rather than modification to individual management practices. This perhaps means it is more difficult to make valid and useful comparisons of biophysical properties than economic ones. It is important to separate out those aspects of the system that need to be assessed at the whole systems level (i.e. those which are dominated by interactions or large-scale ecological processes, and those which can be compared at the small plot scale) (Watson and Atkinson 2000).

In the trials listed in Table 15.3 and Table 15.4 the study areas vary from relatively small plots, such as the DOK (bioDynamic–Organic–Konventional) trial (Mäder *et al.* 2002), to several hectares (e.g. Leake 1996). One complicating factor in interpreting results of these trials is whether they truly compare farming systems or simply rotations. Factorial crop rotation experiments (e.g. Mäder *et al.* 2002, Watson *et al.* 1999) and field-scale testing of crop rotations (e.g. Cormack 1999) that allow factorial experiments within them, contribute to different aspects of the understanding of how crop rotations function. As soon as the crops or even varieties within a rotation are changed the effect of that rotation both in terms of yield and productivity as well as soil structure and environmental impact will change, regardless of the production system. However, under given soil and climatic constraints the most productive choice of crops and varieties in a rotation will differ depending on whether the system is managed conventionally or organically. Thus, are any differences between the biophysical aspects of the rotation due to the system or the rotation? The DOK trial in Switzerland has compared the same crop rotation under different systems of manuring and pest management since 1978 (Mäder *et al.* 2002). Although this trial has provided a wealth of interesting information on soil properties and crop protection and production but the question remains as to how applicable this information is in the context of practical farming. Despite the reliance on forage legumes for fertility building in many organic systems, surprisingly few trials include grazing livestock. Many trials utilise livestock manure to mimic whole systems, but these can never truly represent realistic grazing situations where there is constant interaction between soils and plant and animal production.

Lack of replication is a drawback of many of the trials in Table 15.3 and Table 15.4 (e.g. two replicates in the SAC crop rotations trials) (Watson *et al.* 1999). Lack of replication and the non-use of livestock perhaps both reflect the costs and funding commitment needed to run trials of this type. Some of the difficulties of running rotation trials are discussed in Taylor *et al.* (2002). Olesen (1999) recommends the involvement of experts from outside individual research groups in the design of long-term experiments. This would increase the rigour of the experimental design by drawing on wide experience from past experimentation. It can also help to add value to experiments by ensuring that design factors such as plot size are appropriate for all the parameters likely to be studied in the experiment.

Where studies are carried out within organic systems (e.g. Table 15.4), it is particularly important that background information on aspects like time since conversion and the particular

Table 15.3 Examples of long-term experiments that compare organic cropping systems with conventional and other systems

Name	Site	Start date	Systems compared (O, B, L, C[A])	Rotation	Reference
K-Trial	Järna, Sweden	1958–1990	B, C	Ley/arable + manure	Granstedt and Kjellenberg (1997)
DOK trial	Frick, Switzerland	1978	O, B, C	Ley/arable + manure	Mäder *et al.* (2002)
Long-term fertilisation trial	Darmstadt, Germany	1980	O, B, C	Arable + manure	Raupp (2001)
Farming Systems Trial	Pennsylvania, USA	1981	O, C	Arable + manure	Drinkwater *et al.* (1998)
Cropping systems trial	Foulum, Denmark	1987	O, L, C	Ley/arable + manure/ grazing	Mikkelsen and Rasmussen (1994)
Focus on Farming Practice	Leicester, UK	1989	O, L, C	Ley/arable and stockless	Leake (1996)
Apelsvoll cropping systems experiment	Norway	1990	O, L, C	Ley/arable and stockless	Eltun (1994)
Glenlea Study	Manitoba, Canada	1992	O,L,C	Stockless arable	Gleanlea Study (2005)
Long-Term Research on Agricultural Systems	California, USA	1993	O, L, C	Stockless arable/ horticulture	Denison *et al.* (2004)
Apple production systems	Washington, USA	1994	O, L, C	Apple orchard	Reganold *et al.* 2001
Farming Systems Project	Maryland, USA	1996	O, C	Stockless arable	USDA 2006
Mediterranean Arable Systems Comparison Trial	Pisa, Italy	2001	O, C	Stockless arable	CIRAA 2006

[A] O, Organic; B, biodynamic; L, low input or integrated; C, conventional.

Table 15.4 Examples of long-term experiments that compare different organic cropping systems

Name	Site	Start date	No. of organic systems compared	Rotation	Reference
Stockless Trial, Elm Farm Research Station	Berkshire, UK	1987	4	Stockless arable	Philipps *et al.* (1999)
Rotations Trial, Scottish Agricultural College	Aberdeen, UK	1991	2	Ley/arable, grazed by sheep	Watson *et al.* (1999)
Ty Gwyn	Aberystwyth, UK	1992	2	Dairy	IGER (1996)
DARCOF Rotations Trial (EXUNIT)	4 sites, Denmark	1997	4	Arable + manure	Olesen *et al.* (1999)

standards applied are included (Lund and Algers 2003). The location of the experiment in terms of soil and climate is also an important context for the results. The Danish crop rotation experiments are carried out at four different locations in Denmark (Olesen *et al.* 1999), and even within this fairly small geographical area the results so far show clear differences between the different locations (Askegaard *et al.* 2004). The differences are not only in yields, but also in the interactions between location (soil, climate) and rotations. A further issue is that the organic standards have changed over time (Woodward and Vogtmann 2004), meaning that past research carried out within organic systems may not be applicable today. One example of this is Watson *et al.* (1993) who describe a farm that imports large quantities of conventional poultry manure. Trewavas (2001) quotes this work to show that organic farming is unsustainable although the system in question would now not be certifiable. Regional differences in standards also need to be accounted for in comparing published literature. Lund and Algers (2003) give examples of how the organic animal husbandry standards differ between three neighbouring European countries.

There are also many organic experimental farms used in organic research, but these farms are less well documented in the literature than the long-term experiments. In Zanoli and Krell (1999) a preliminary overview is given of some of these farms. Case studies (e.g. Cobb *et al.* 1999) are a good example of how the socioeconomic and biophysical aspects of organic farming can be brought together.

Participatory research

Participatory research methods, which have been commonly used in developing countries (e.g. Bellon 2001), are now being widely accepted in industrialised countries in both conventional (e.g. Cerf *et al* 2000) and organic farming (e.g. Krell and Zanoli 2000, Andrews *et al.* 2002). A range of participatory research methods are used from action research to on-farm research. In action research, the research goals are determined by the participants in the system in question. On-farm research, however, may be more or less 'participatory' depending on how much the farmer, farm workers, advisers and others are involved in the research. There is, thus, no sharp dividing line between on-farm research and the experimental research farms mentioned above.

Cross-disciplinary research

The desire to make research in organic agriculture more holistic or systemic is based on ideas and aims within the organic movement: a holistic perception of health, aspirations towards more fair food systems, and aims to farm in systems that are more self-sufficient, based on natural structures and processes within the system, and with limited options for utilising outside inputs as a means to improve growth and protect against pests and diseases. The same desire can also be found partly within research in conventional agriculture based primarily on the recognition of farms as systems in their own right. But due to the comprehensive ideas and aims of organic agriculture, there is a particular emphasis on the problems related to science being fragmented by disciplinary specialisation. Some in the science community have traditionally undervalued the need for interdisciplinary and transdisciplinary work and for methodological and organisational structures that can facilitate such work (Dalgaard *et al.* 2003) although recent advances in whole-farm research methods are creating the methods and structures needed to carry out robust holistic research (e.g. Firbank *et al.* 2003, Perry *et al.* 2003).

The notions of systemic science and wholeness-oriented research seem to capture essential features of an important shift in the conception of what science is as well as in the general methodology and structure of science. The shift is related to the involvement of science in new complex areas, such as the socioecological problems of society and environment. Here, different disciplines such as ethics, sociology, ecology and chemistry ought to be in close cooperation. This is not often the case and there is thus a need for systemic research methodologies that enable transdisciplinary research efforts (Alrøe and Kristensen 2002).

Cross-disciplinary research approaches need to build on an understanding of how different methods relate to their 'research world', and what this means. For example, if laboratory research, field trials, crop rotation experiments and on-farm research are compared, they differ in complexity, and subsequently in the conditions for experimentation and control, and thereby for replications or reproductions of phenomena. They also differ with respect to the need for ethical considerations. Furthermore, systemic approaches that include, for example, the human and social parts of the agricultural systems into their research world are often perceived as less scientific than conventional, analytical approaches, which have delimited their research worlds to exclude those aspects of reality. However, these obviously different approaches are not different in their potential for doing good science. This recognition can serve as a basis for a reflexive discussion of the focus and meaning conveyed by different research perspectives and the strengths and weaknesses of different research methods in cross-disciplinary research approaches.

In Figure 15.1, some examples of different disciplines and methods relevant to organic research are placed in relation to two methodological dimensions. One is the complexity of the research world described above. The other is the degree of involvement of the researcher or the 'research unit' in its research world. The triangular form illustrates that in simple and well-controlled research worlds, the detached and involved phases of research can be employed in close cooperation, whereas detached, descriptive, historical methods are widely different from involved, interactive, developmental action research methods though they both work with complex research worlds.

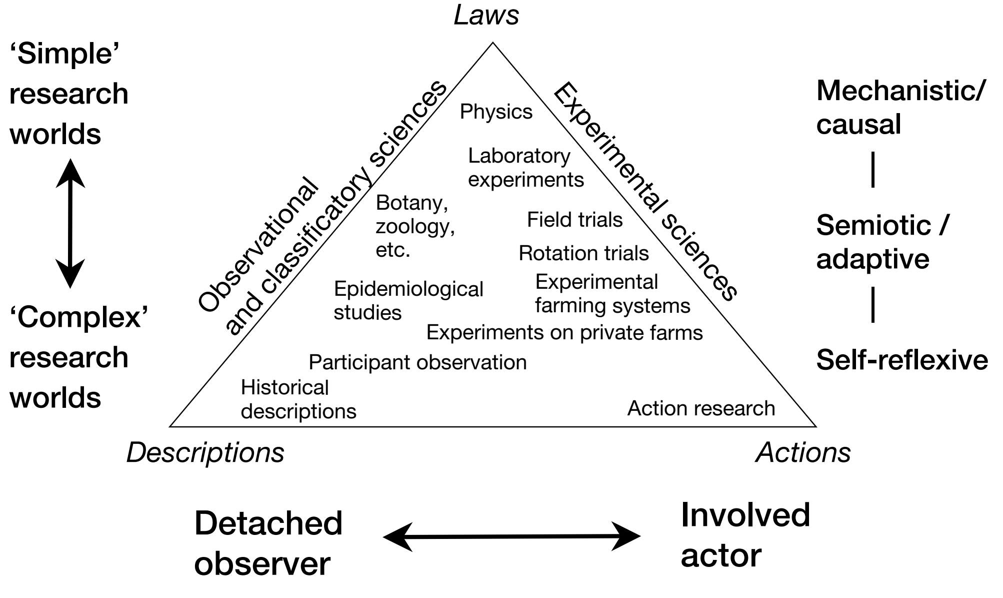

Figure 15.1 Some research disciplines and methods of relevance for organic research ordered according to two methodological dimensions: the complexity of the research world (spanning from causal over adaptive to self-reflexive entities) and the degree of involvement of the researcher (adapted from Alrøe and Kristensen 2002). The triangular form shows that simple research worlds allow the researcher to intervene and withdraw from the research world in closely connected processes, whereas the involved and detached stances are widely different in relation to complex research worlds.

The epistemological limitation with regard to using causal knowledge from simple research worlds is that some aspects are neglected because of the reduction. Some examples of neglected aspects are crop rotation effects when doing research on single fields, the effects on farm economics when doing research on cropping systems, the role of motivation (intention) in behavioural studies, and the management factor when studying farm dynamics in experimental farming systems or in the assessment of animal welfare.

Agriculture is, by definition, about management. Lockeretz (2000) describes organic farming as interfering with nature just enough to get the job done, in comparison to conventional agriculture which at times creates completely artificial environments. Regardless of the system, the role of the human being is central to the success of that system. The human role is most often highlighted in relation to animal health and welfare but is just as likely to apply to crop and soil husbandry. Martini *et al.* (2004) question the assertion that yield improvements following conversion to organic production are related to improvements in soil quality and suggest that they may relate to improved management skills and experience. Accounting for the role of the manager thus becomes critical in comparative studies of systems. Trewavas (2004) asserts that the only way to make a fair comparison between organic and conventional farming is to use matched fields, on the same farm, managed by the same person. Although this may overcome some of the difficulties in edaphic and climatic factors, it may negate the comparison because it has been shown many times that organic and conventional farmers have different attitudes to crop and animal husbandry (e.g. Lund and Algers 2002). There is also evidence that as the organic farming sector grows in size, there are accompanying changes in the type, and philosophy, of farmers going organic (Lund *et al.* 2002).

In general, there are methodological and technical limits to doing more holistic research because of the complexity and diversity of the research worlds. For example, it is difficult to make a general predictive model of a complex research world. This is particularly true if this world involves people, companies and organisations, which are self-reflexive and therefore adapt and change their perceptions of themselves in accordance with the knowledge they gain from the model presented by the researchers. There are also ethical limits to research in complex worlds, connected to the presence of humans, animals and ecosystems, which the researchers have a moral responsibility to take into consideration and, in the case of people, to involve them in these ethical considerations (see also Latour and Woolgar 1979). In this perspective, reduction entails (apart from methodological benefits) that the ethical questions are externalised – they become part of the external communications of science and the actual research can be done without ethical considerations. In a wider systemic perspective, however, where science is seen as a part of society and nature, and with reference to the criterion of relevance or (more generally) given the idea that science is morally responsible for its actions (Jonas 1984, Alrøe and Kristensen 2003), there can be decisive ethical concerns connected with the potential consequences of reductive research methods. The development and implementation of a comprehensive systemic research methodology that enables transdisciplinary research must, therefore, also involve normative sciences that are concerned with ethics and how to do good science.

Future perspectives on research approaches

The role of institutions and individuals in organic research

Across the world research on organic farming is carried out within a range of universities, colleges, research institutes and private consultancies as well as by dedicated organic organisations. The nature of ‘conventional’ or ‘mainstream’ organisations versus dedicated organic organisations brings with it different approaches to research and to the promulgation of research results. The attitudes and cultures of both individual researchers and organisations are important in determining research approaches, interpretation of research findings and efficiency of transfer of research results to the end-user community. Linkages between non-governmental and governmental organisations have been particularly recognised as valuable within the organic farming sector in developing countries (Shrum 2000). As with all agricultural research, the nature and direction of research is perhaps most strongly influenced by the source of funding.

Scientists working within state-funded organisations, where research is carried out on several types of farming systems, may find themselves faced with different challenges to those working in 'organic-only' institutes (Watson and Atkinson 2002). Wynen (1997) notes that few 'career scientists' have chosen to get involved in organic farming as there is a lack of recognition of the validity of the subject among the conventional science community. The existence of organisations like the Danish Research Centre for Organic Farming (DARCOF), and the growing involvement of universities and conventional institutes in organic research, is changing this attitude slowly. For organisations with multiple interests there are physical and human resource implications to organic farming research. Alongside the investment in research facilities for systems research and long-term experiments, there is likely to be a need to duplicate equipment and personnel where systems are fundamentally incompatible. For example, where the same organisation is researching both genetically modified organisms and organic farming, there are both ethical and practical reasons for running two entirely separate research teams.

Multifunctional organisations that traditionally have had a responsibility for technology transfer in addition to research may have taken a different approach to organisations with a sole focus on research. For example, for those working directly with farmers, research aimed at understanding and improving organic farming is likely to be more important than comparisons between different systems. However, the paradigm shift towards end-user relevance and stakeholder involvement in research is resulting in changes in approach among the more traditional research organisations.

Research training and education

Despite the rigours of scientific training, the culture of the organisation and the nature of the individual scientists involved will influence both research design and data interpretation. In aiming to understand something as complex as the functioning of systems, the scope for different interpretations of experimental data is likely to be greater than in reductionist experimentation. Scientific training at tertiary level tends to include a high degree of specialisation and encourages monodisciplinary rather than interdisciplinary thinking. Scientists need to be able to contribute not only from their own disciplines but also to recognise the disciplinary part of the bigger jigsaw, as well as being able to 'step outside their own discipline when it becomes a hindrance rather than a help' (Lockeretz 2000). There is a need to address training needs of researchers involved in organic farming to ensure that they do understand the systems within which they are working. Teams where systems thinkers and disciplinary thinkers can work effectively as one are needed.

On the use of conventional research in an organic context

Research on organic farming is often, correctly, focused on the development of systems that prevent problems such as pests, diseases or nutrient shortages. Contrastingly much conventional research has focused on finding short-term interventionist solutions to such problems. The commodity based thinking prevalent in agriculture has also contributed to this paradigm.

Ongoing changes in mainstream agriculture, particularly those driven by the environmental and human health agendas of reducing pesticide use and environmental contamination are likely to narrow the gap between organic and conventional research needs. The focus of much conventional research on finding new, acceptable input products to solve technical problems will have to be replaced by research of the ecological and social aspects that will allow inputs to be reduced. This change should allow wider application of research on organic farming to conventional systems and *vice versa*. In the past, the conventional sector has sometimes claimed that zero N or zero agrochemical treatments in variety trials are relevant information for organic agriculture. This shows a misunderstanding of the systems concept of organic farming which means that crop production in organic systems is more a function of past cropping and environment than of current management, a concept described by Olesen (1999) as the 'memory' of the system.

Research in organic farming – peer reviews and publication

It is relatively easy to quantify research effort in terms of amounts of government money spent on organic farming. It is harder to quantify the outcomes of this research and more difficult still to estimate its value to the industry. Conventionally, research output in UK universities and research institutions is on the basis of refereed publication output. The number of refereed journal articles produced annually with the words organic, biological, ecological or biodynamic farm, farms, agriculture or farming in the title, keywords or abstract has increased dramatically since 1980. The number of refereed publications cited in the Science Citation Index on organic farming increased from 21 in 1981–1985 to 286 between 1996 and 2000 (Watson and Atkinson 2002). This clearly reflects an increase in research funding but may also reflect a greater acceptance of the importance of understanding the underlying biology and socioeconomics of organic systems. Although publication in high impact factor refereed publications may be a suitable indicator of scientific quality in fundamental science, it is less useful in applied science (as defined by OECD 2003). Several researchers have highlighted difficulties in publishing work on organic farming systems in refereed journals (e.g. MacRae *et al.* 1989). Two journals were started explicitly to allow publication of such work: the *American Journal of Alternative Agriculture* (1986) (now titled *Renewable Agriculture and Food Systems*) and *Biological Agriculture and Horticulture* (1982). Neither of these journals is highly rated through the conventionally used impact factor system that depends on citations in other refereed journals. Publication of studies of organic farming has become much more common in mainstream agricultural systems journals, although there is still concern among scientists over publication of truly interdisciplinary work, especially research that aims to integrate the social and natural sciences.

To this end, the *International Journal of Agricultural Sustainability* was started in 2003.

A 'fit for purpose' criterion may be much more useful in trying to assess the value of applied organic farming research to end-users. With respect to organic farming, much of the research has been reported in conference proceedings and other forms of grey literature as illustrated by the inclusion of over 100,000 abstracts on organic research on the CABI publishing website (CABI 2006). Grey literature has been one of the most prevalent routes of knowledge transfer in organic farming (Woodward 2002a). There are often long lags between expenditure and final output from research, estimated by Barnes (1999) of 16 years and upwards. Participative approaches to research may cut this time lag significantly with regard to stakeholders. Preprint archives with full-text papers can speed up the communication to other researchers considerably (e.g. Taubes 1996). The recently established web-based archive Organic Eprints (Organic Eprints 2006) is an open, international archive for research in organic agriculture that accepts, for example, preprints, published papers, reports, project descriptions and popular articles. The main objectives of the archive are to facilitate the communication of research papers and proposals, to improve the dissemination and impact of research findings, and to document the research effort. In 2005 it included 2700 papers and received more than 50,000 visits per month. Nevertheless refereed journal output will probably continue for some while to be a dominant marker in agricultural science to gain both respect and reward for individuals and organisations.

Coordination of organic research

Many countries have either a formal or informal network of organic researchers. The following are examples of how these networks operate in different countries. Scientific Congress on Organic Agriculture Research (SCOAR) launched by the Organic Farming Research Foundation in the USA brings together producers and scientists to build a long-term organic research agenda (Sooby 2001). The Organic Agriculture Centre for Canada (OACC 2005) founded in 2001, and funded through Agriculture and Agri-Food Canada and the Natural Sciences and Engineering Research Council with additional funding from seven provinces, coordinates and collaboratively develops research with agricultural schools in several Canadian universities. In the UK, the Colloquium of Organic Researchers was formed in 2000 to provide a discussion forum for issues unique to organic research. In the Netherlands researchers from the private Louis Bolk Institute are involved as external experts in projects on organic farming carried out in conventional organisations, to ensure their appropriateness and relevance to organic agriculture (Niggli 2002). In Denmark, the Danish Research Centre for Organic Farming, described as a research institute 'without walls' coordinates state funded projects on organic farming carried out at a range of institutions. There are other initiatives such as conferences and workshops for organic farming research in the Nordic countries and in the German-speaking countries.

In June 2003, the International Society of Organic Agriculture Research (ISOFAR) was launched in Germany. ISOFAR has 12 sections, mainly based on disciplines, and five cross-disciplinary working groups. The latter address issues such as the relationship between organic agriculture and biotechnology, methodological approaches to organic research and coordination of long-term experiments (ISOFAR 2006).

Across Europe there are many different institutes and traditions for organic farming research that until now have not been coordinated. Many of the research groups involved are geographically isolated and lack 'critical mass'.

As part of the EU ERANET scheme, the EU hopes to exploit the potential for improved research quality and value-for-money through transnational cooperation. The overall objective of CORE Organic (Coordination of European Transnational Research in Organic Food and Farming) is to enhance quality, relevance and utilisation of resources in research in organic food and farming in the EU. This will be achieved by research cooperation and coordination of research facilities, and to establish a joint pool of at least three million Euro per year for transnational research in organic food and farming by the end of the project in 2007 (CORE 2006). The aims are set out in Box 15.3.

Box 15.3 Aims of CORE Organic

1 Increase exchange of information and establishment of a common open web based archive.
2 Coordination of existing research and integration of knowledge.
3 Sharing and developing best practice for evaluating organic research.
4 Identification and coordination of future research.

One of the activities that will be carried out in CORE Organic is a research priorities exercise aimed at involving a wide variety of stakeholders in the organic sector, from producers to consumers. A UK exercise is being carried out as a pilot for this wider study during 2005. Previous exercises in establishing organic research priorities in the UK have tended to consult a fairly narrow range of stakeholders and have focused on technical rather than social issues. Reed (2004) argues strongly for social science to move up on the organic research agenda. At least in European terms, the basis for this is that following the reform of the Common Agricultural Policy, organic farming may be more important as a means of bringing a diverse range of added benefits to rural communities than as a system of food production.

Conclusions

Research is important in the development of organic food and farming. To fulfil this role a broad range of methods and approaches is needed. There is no single kind of scientific method that is adequate and there is also a need to develop new methods and approaches. It is a great challenge to include very different methods, applied within a wide range of perspectives, in an interdisciplinary or transdisciplinary research effort. There are no essential barriers to establishing such cross-disciplinary research collaborations but there are many practical and structural barriers. The recent initiatives on increased international research cooperation within organic research will, however, help to realise more comprehensive research efforts by forming organic research communities that, for example, share experiences, provide for expensive facilities for large-scale and long-term systems research and coordinate research initiatives. There are also many ways in which research in organic agriculture can benefit from cooperation with mainstream agricultural research. These options increase in step with the establishment of ways of organising organic research that promote such interaction and with the changing research agendas for conventional research. Despite these benefits, and because of the positive integration of organic research into mainstream institutes, there is still a clear need to sustain dedicated organic research institutes and to foster new international research networks and organisations that focus entirely on organic research.

References

Alrøe, H.F. and Kristensen, E.S. 2002. Towards a systemic research methodology in agriculture: Rethinking the role of values in science. *Agriculture and Human Values* 19: 3–23.

Alrøe, H.F. and Kristensen, E.S. 2003. Toward a systemic ethic: in search of an ethical basis for sustainability and precaution. *Environmental Ethics* 25: 59–78.

Alrøe, H.F. and Kristensen, E.S. 2004. Why have basic principles for organic agriculture? And what kind of principles should they be? *Ecology and Farming* 36: 27–30.

Andrews, S.S., Mitchell, J.P., Mancinelli, R., Karlen, D.L., Hartz, T.K., Horwath, W.R., Pettygrove, G.S., Scow, K.M. and Munk, D.S. 2002. On-farm assessment of soil quality in California's Central Valley. *Agronomy Journal* 94: 12–23.

Askegaard, M., Olesen, J.E., Rasmussen, I.A., Driessen, E., Nielsen, E., Thomsen, H.C., Bak, H. and Lindberg, J.F. 2004. Økologiske sædskifter til produktion af korn. *Grøn Viden*, Markbrug nr. 298.

Atkinson, D., Watson, C.A., Pearce, B., Woodward, L., Wolfe, M., Welsh, J. and Nowack, K. 2002. Organic agriculture and GM crops. In: *BCPC Conference, 2002 – Pests and Diseases*. British Crop Protection Council, Surrey. pp. 523–530.

Balfour, E.B. 1943. *The Living Soil*. Faber and Faber, London.

Barnes, A.P. 2002. Publicly-funded UK agricultural R&D and 'social' total factor productivity. *Agricultural Economics* 27: 65–74.

Bellon, M.R. 2001. *Participatory, Research Methods for Technology Evaluation: A Manual for Scientists Working with Farmers*. CIMMYT, Mexico, DF.

Blakemore, R.J. 2000. Ecology of earthworms under the 'Haughley Experiment' of organic and conventional management regimes. *Biological Agriculture and Horticulture* 18: 141–159.

CABI 2006. *Organic Research Database*. CAB International, Wallingford. <http://www.organic-research.com>. Accessed 17/1/06.

Carpenter-Boggs L, Kennedy, A.C. and Reganold, J.P. (2000) Organic and biodynamic management: effects on soil biology *Soil Science Society of America Journal* 64: 1651–1659.

Cerf, M., Gibbon, D., Hubert, B., Ison, R., Jiggins, J., Paine, M., Proost, J. and Röling, N. (2000) (Eds) *Cow Up a Tree. Knowing and Learning for Change in Agriculture and Rural Development. Case Studies from Industrialised Countries*. INRA Éditions, Paris.

CIRAA 2006. *Organic Farming – Long-term Systems Comparison Experiment (MASCOT)*. Centro Interdipartimentale di Ricerche Agro-Ambientali 'Enrico Avanzi', University of Pisa, Pisa. <http://www.avanzi.unipi.it/researchactiviti_file/Organic_farming_ENG.htm>. Accessed 17/1/06.

Cobb, D., Feber, R., Hopkins, A., Stockdale, L., O'Riordan, T., Clements, B., Firbank, L., Goulding, K., Jarvis, S. and Macdonald, D. 1999. Integrating the environmental and economic consequences of converting to organic agriculture: evidence from a case study. *Land Use Policy* 16: 207–221.

Commission of the European Communities 2004. *European Action Plan on Organic Farming. Commission Working Document. SEC (2004) 739*. European Commission, Brussels.

CORE Organic 2006. *CORE Organic - Joining Resources to Improve Research in Organic Food and Farming*. Coordination of European Transnational Research in Organic Food and Farming, Tjele. <http://www.core-organic.org>. Accessed 17/1/06.

Cormack, W.F. 1999. Testing a stockless arable organic rotation on a fertile soil. In: Olesen, J. E., Eltun, R., Gooding, M.J., Jensen, E.S. and Köpke, U. (eds) *Designing and Testing Crop Rotations for Organic Farming*. DARCOF, Tjele. pp. 115–124.

Dalgaard, T., Hutchings, N.J. and Porter, J.R. 2003. Agroecology, scaling and interdisciplinarity. *Agriculture, Ecosystems and Environment* 100: 39–51.

Defra 2002. *Action Plan to Develop Organic Food and Farming in England*. Defra, London.

Delate, K. and DeWitt, J. 2004. Building a farmer-centred land grant university organic agriculture program: a Midwestern partnership. *Renewable Agriculture and Food Systems* 19: 80–91.

Denison, R.F., Bryant, D.C. and Kearney, T.E. 2004. Crop yields over the first nine years of LTRAS, a long-term comparison of field crop systems in a Mediterranean climate. *Field Crops Research* 86: 267–277.

Drinkwater, L.E., Wagoner, P. and Sarrantonio, M. 1998. Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature* 396: 262–265.

Duthie, G.C. 2001. Anthocyanin-rich extract decreases indices of lipid peroxidation and DNA damage in Vitamin E depleted rats. *Free Radical Biology and Medicine* 31: 1033–1037.

Elm Farm Research Centre 2003. *A Review of UK Research and Development for Organic Food and Farming*. Report OF0338 for Department of Environment, Food and Rural Affairs, London. Elm Farm Research Centre, Newbury.

Eltun, R. 1994. The Apelsvoll cropping system experiment. I. Background, objectives and methods. *Norwegian Journal of Agricultural Sciences* 8: 301–315.

Firbank, L.G., Heard, M.S., Woiwod, I.P., Hawes, C., Haughton, A.J., Champion, G.T., Scott, R.J., Hill, M.O., Dewar, A.M., Squire, G.R., May, M.J., Brooks, D.R., Bohan, D.A., Daniels, R.E., Osborne, J.L., Roy, D.B., Black, H.I.J., Rothery, P. and Perry, J.N. 2003. An introduction to the farm-scale evaluations of genetically modified herbicide-tolerant crops. *Journal of Applied Ecology* 40: 2–16.

Glenlea Study 2005. *Welcome to the Glenlea Study – Canada's Oldest Organic-Conventional Cropping Comparison Study. History of the Glenlea Study.* Department of Plant Science, University of Manitoba, Winnipeg. <http://www.umanitoba.ca/faculties/afs/plant_science/glenlea/glenleahistory.html >. Accessed 17/1/06.

Granstedt, A. and Kjellenberg, L. 1997. Long-term field experiment in Sweden: effects of organic and inorganic fertilizers on soil fertility and crop quality. In: Lockeretz, W. (ed.) *Agricultural Production and Nutrition*. Tufts University, Boston. pp. 79–90.

Howard, A. 1943. *An Agricultural Testament*. Oxford University Press, Oxford.

IFOAM 2002. *IFOAM Basic Standards for Organic Production and Processing.* IFOAM, Tholey-Theley, Germany.

IGER 1996. Conversion to organic milk production. In: Hagger, R. and Padel, S. (eds) *IGER Technical Review Number 4*. Institute of Grassland and Environmental Research, Aberystwyth.

ISOFAR 2006. *International Society of Organic Agriculture Research*. ISOFAR, Bonn. <http://www.isofar.org>. Accessed 17/1/06.

Jawson, M.D. and Bull, C.T. 2002. USDA research into organic farming. *American Journal of Alternative Agriculture* 17: 201–202.

Jonas, H. 1984. *The Imperative of Responsibility. In Search of an Ethics for the Technological Age*. University of Chicago Press: Chicago.

Koepf, H.H. 1993. *Research in Biodynamic Agriculture: Methods and Results*. Bio-Dynamic Farming and Gardening Association, Kimberton.

Krell, R. and Zanoli, R. 2000. (eds) *Research Methodologies in Organic farming: On-Farm Participatory Research*. *REU Technical Series 63*. FAO, Rome.

Kristensen, E.S. and Halberg, N. 1997. A systems approach for assessing sustainability in livestock farms. In: Sørensen, J.T. (ed.) *Livestock Farming Systems. More Than Food Production. Proceedings of the 4th International Symposium on Livestock Farming Systems*. European Association for Animal Production, Wageningen. pp. 16–30.

Lampkin, N.H. 1994. Researching organic farming systems. In: Lampkin, N.H. and Padel, S. (eds) *The Economics of Organic Farming: An International Perspective*. CAB International, Wallingford. pp. 27–44.

Lantinga, E. 2001. Presentation on nutrient balances. In: *Workshop on Organic farming, System Thinking and the Future*. 21–23 February 2001. International Agricultural Centre, Wageningen, the Netherlands.

Latour, B. and Woolgar, S. 1979. *Laboratory Life: The Social Construction of Scientific Facts*. Sage, Beverly Hills.

Lauridsen, C., Jørgensen, H., Halekoh, U., Christensen, L.P. and Brandt, K. 2005. Organic diet enhanced the health of rats. *DARCOFenews*. March.

Leake, A.R. 1996. The effect of cropping sequences and rotational management: an economic comparison of conventional, integrated and organic systems. *Aspects of Applied Biology* 47: 185–195.

Lockeretz, W. 2000. Organic farming research today and tomorrow. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *IFOAM 2000 – The World Grows Organic. Proceedings of the 13th IFOAM Conference*. vdf Hochschulverlag AG an der ETH Zurich, Basel. pp. 718–720.

Lockeretz, W. and Anderson, M.D. 1993. *Agricultural Research Alternatives*. University of Nebraska Press: Lincoln.

Lockeretz, W. and Boehncke, E. 2000. Agricultural systems research. In: Hovi, M. and Garcia Trujillo, R. (eds) *Diversity of Livestock Systems and Definition of Animal Welfare. Proceedings of the 2nd NAHWOA Workshop*. Veterinary Epidemiology and Economics Research Unit, Reading, pp. 5–12.

Lund, V. and Algers, B. 2003. Research on animal health and welfare in organic farming – A literature review. *Livestock Production Science* 80: 55–68.

Lund, V., Hemlin, S. and Lockeretz, W. 2002. Organic livestock production as viewed by Swedish farmers and organic initiators. *Agriculture and Human Values* 19: 255–268.

MacRae, R.J., Hill, S.B., Henning J, Mehuys, G.R. (1989) Agricultural science and sustainable agriculture: a review of the existing scientific barriers to sustainable food production and potential solutions. *Biological Agriculture and Horticulture* 6, 173–219.

Mäder, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P., Niggli, U. 2002. Soil fertility and biodiversity in organic farming. *Science* 296: 1694–1697.

Martini, E.A., Buyer, J.S., Bryant, D.C., Hartz, T.K. and Denison, R.F. 2004. Yield increases during the organic transition: improving soil quality or increasing experience? *Field Crops Research* 86: 255–266.

Mikkelsen, G. and Rasmussen, K.J. 1994. Research in cropping systems in Denmark. The design and evolution of the integrated strategy for cropping systems with special attention on soil tillage and utilization of organic matter. In: *Proceedings of the 13th International Conference of the Soil Tillage Research Organization*. International Soil Tillage Research Organization, Aalborg. pp. 729–736.

Niggli, U. 2002. The contribution of research to the development of organic farming in Europe. In: Powell, J. (ed.) *Proceedings of the UK Organic Research 2002 Conference: Research in Context*. 26–28 March 2002, Aberystwyth. Organic Centre Wales, Institute of Rural Studies, University of Wales Aberystwyth, Aberystwyth. pp. 19–24.

Niggli, U. and Willer, H. 2001. Stimulating the potential for innovation in organic farming by research. In: Danish Ministry of Agriculture and Fisheries (ed.) *Proceedings – Organic Food and Farming – Towards Partnership and Action in Europe*. Copenhagen, Denmark, 10–11 May 2001. Danish Ministry of Agriculture and Fisheries, Copenhagen. pp. 194–203.

OACC 2005. *Information about OACC Partnerships*. Organic Agriculture Centre of Canada, Truro. <http://www.organicagcentre.ca/FriendsAndPartners/oacc_partners_info.html>. Accessed 17/1/06.

OECD 2003. *Frascati Manual 2002 Proposed Standard Practice for Surveys on Research and Experimental Development*. Organisation of Economic Cooperation and Development, Paris.

Olesen, J.E. 1999. Perspectives for research on cropping systems In: Olesen, J.E., Eltun, R., Gooding, M.J., Jensen, E.S. and Köpke, U. (eds) *Designing and Testing Crop Rotations for Organic Farming*. DARCOF, Tjele. pp. 11–20.

Olesen, J.E., Rasmussen, I.A., Askegaard, M. and Kristensen, K. 1999. Design of the Danish crop rotation experiment. In: Olesen, J.E., Eltun, R., Gooding, M.J., Jensen, E.S. and Köpke, U. (eds) *Designing and Testing Crop Rotations for Organic Farming*. DARCOF, Tjele. pp. 49–62.

Organic Eprints 2006. *Organic Eprints*. Danish Research Centre for Organic Farming, Forschungsinstitut für biologischen Landbau and Bundesprogramm Ökologischer Landbau, Tjele, Frick and Bonn. <http://orgprints.org>. Accessed 17/1/06.

Parr, J.F. 2003. USDA research on organic farming. *American Journal of Alternative Agriculture* 18: 171–172.

Perry, J.N., Rothery, P., Clark, S.J., Heard, M.S. and Hawes, C. 2003. Design, analysis and statistical power of the Farm-Scale Evaluations of genetically modified herbicide-tolerant crops. *Journal of Applied Ecology* 40: 17–31.

Pfeiffer, E. 1975. *Sensitive Crystallisation Processes: A Demonstration of Formative Forces in the Blood*. Anthroposophic Press, New York.

Philipps, L., Welsh, J.P. and Wolfe, M.S. 1999. Ten years experience of all-arable rotations. In: Olesen, J.E., Eltun, R., Gooding, M.J., Jensen, E.S. and Köpke, U. (eds) *Designing and Testing Crop Rotations for Organic Farming*. DARCOF, Tjele. pp. 71–78.

POA Task Force. 2005. *Elaborated Draft of Principles of Organic Agriculture, January 17th 2005*. <http://ecowiki.org/IfoamPrinciples/WorkPlan>. Accessed 31/8/05.

Ramirez-Tortosa, C., Anderson, Ø., Gardner, P.T., Wood, S.G. Morrice, P.C., Duthie, S.J., Collins, A.R. and Duthie, G.C. 2001. Anthocyanin-rich extract decreases indices of lipid peroxidation and DNA damage in Vitamin E depleted rats. *Free Radical Biology and Medicine* 31: 1033–1037.

Raupp, J. 2001. Manure fertilization for soil organic matter maintenance and its effects upon crops and the environment, evaluated in a long-term trial. In: Rees, R.M., Ball, B.C., Campbell, C.D. and Watson, C.A. (eds) *Sustainable Management of Soil Organic Matter*. CAB International, Wallingford. pp. 301–308.

Reed, M. 2004. *More Than Just Fashionable Foods – the Importance of the Social Sciences in Organic Research*. <http://www.organic-research.com/Reviews.asp?action=display&openMenu=relatedItems&ReviewID=1135&Year=2004>. Accessed 31/8/05.

Reganold, J.P., Glover, J.D., Andrews, P.K. and Hinman, H.R. (2001) Sustainability of three apple production systems. *Nature* 410: 926–929.

Reganold, J.P., Palmer, A.S., Lockhart, J.C. and Macgregor, A.N. 1993. Soil quality and financial performance of biodynamic and conventional farms in New Zealand. *Science* 344–349.

RIRDC 2005. *Organic Produce Research Program*. Rural Industries Research and Development Corporation, Barton. <http://www.rirdc.gov.au/programs/org.html>. Accessed 31/8/05.

Rowe, J.S. 1997. From reductionism to holism in ecology and deep ecology. *The Ecologist* 27: 147–151.

Schjønning, P., Elmholt, S. and Christensen, B.T. 2004. Soil quality management – concepts and terms. In: Schjønning, P., Elmholt, S. and Christensen. B.T. (eds) *Managing Soil Quality: Challenges in Modern Agriculture*. CABI Publishing, Wallingford. pp. 1–16.

Shrum, W. 2000. Science and story in development: the emergence of non-governmental organizations in agricultural research. *Social Studies of Science* 30: 95–124.

Sooby, J. 2001. *State of the States. Organic Farming Research at Land Grant Institutions 2000–2001*. Organic Farming Research Foundation, Santa Cruz.

Spedding, C.R.W. 1975. *An Introduction to Agricultural Systems*. Elsevier Applied Science: London.

Taubes, G. 1996. *Speed of Publication – Stuck in First Gear. Science* 271: 5250: 765.

Taylor, D., Younie, D., Coutts, M., Matheson, S. and Mayer, C. 2002. Experiences designing and managing organic rotations trials. In *Proceedings of the UK Organic Research 2002 Conference*. pp. 37–42. Organic Centre Wales: Aberystwyth.

Thompson, P.B. 1995. *The Spirit of the Soil. Agriculture and Environmental Ethics*. New York: Routledge.

Tinker, P.B. 2000. *Shades of Green*. RASE: Warwickshire.

Trewavas, A. 2004. A critical assessment of organic farming-and-food assertions with particular respect to the UK and the potential environmental benefits of no-till agriculture. *Crop Protection* 23: 751–781.

Trewavas, A.J. 2001. Urban myths of organic farming. *Nature* 410: 409–410.

USDA 2004. *USDA Awards $4.5 Million in Grants for Organic Agriculture Projects (News Release No. 0423.04)*. United States Department of Agriculture, Washington DC. <http://www.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_1OB?contentidonly=true&contentid=2004/09/0423.xml>. Accessed 17/1/06.

USDA 2006. *Long-Term Field Experiment to Evaluate Sustainability of Organic and Conventional Cropping Systems*. United States Department of Agriculture, Washington DC. <http://www.ars.usda.gov/research/projects/projects.htm ?ACCN_NO=407791>. Accessed 17/1/06.

Van Mansfeld. J.D. and Amons, F. 1975. Inquiry into the limits of biological effects of chemical compounds in tissue culture 1 Low dose effects of mercuric oxide. *Zeitschrift für Naturforschung* 30: 643–649.

Watson, C.A. and Atkinson, D. 2002. Organic farming – the appliance of science. In *Proceedings of the UK Organic Research 2002 Conference*. pp. 13–17. Organic Centre Wales, Aberystwyth.

Watson, C.A., Fowler, S.M. and Wilman, D. 1993. Soil inorganic-N and nitrate leaching on organic farms. *Journal of Agricultural Science* 120: 361–369.

Watson, C.A., Younie, D. and Armstrong, G. 1999. Designing crop rotations for organic farming: Importance of the ley-arable balance. In: Olesen, J.E., Eltun, R., Gooding, M.J., Jensen, E.S. and Köpke, U. (eds) *Designing and Testing Crop Rotations for Organic Farming*. DARCOF, Tjele. pp. 91–98.

Williams, C.M. 2002. Nutritional quality of organic food: shades of grey or shades of green? *Proceedings of the Nutrition Society* 61: 19–24.

Woodward, L. 2002a. Organic research – driven and directed by funders? In: Powell, J. (ed.) *Proceedings of the UK Organic Research 2002 Conference: Research in Context. 26–28th March 2002 Aberystwyth*. Organic Centre Wales, Institute of Rural Studies, University of Wales Aberystwyth, Aberystwyth. pp. 7–12.

Woodward, L. 2002b. *Science and Research in Organic Farming*. Elm Farm Research Centre, Newbury.

Woodward, L. and Vogtmann, H. 2004. IFOAM's organic principles. *Ecology and Farming* 36: 24–26.

Woodward, L., Flemming, D. and Vogtmann, H. 1996. Reflections on the past, outlook for the future. In: Østergaard, T.V. (ed.) *Fundamentals of Organic Agriculture. Proceedings Volume I of the 11th IFOAM International Scientific Conference*. IFOAM, Copenhagen. pp. 259–270.

Wynen, E. 1997. *Research on Biological Farming Methods in Europe, Perspectives, Status and Requirements. Biological Farming research in Europe REU Technical Series 54*. FAO, Rome.

Wynen, E. 2003. *Organic Agriculture in Australia – Levies and Expenditure*. Rural Industries Research and Development Corporation, Barton.

Zanoli, R. and Krell, R. (eds) 1999. *Research Methodologies in Organic Farming. REU Technical Series No. 58*. FAO, Rome.

Chapter 16

Education and training in organic agriculture: the Nordic region and the USA

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The importance of education in organic agriculture is growing in many countries, as demand in the marketplace for organic food expands and farmers respond by increasing organic certified areas. Traditionally, most training in organic production practices and systems has taken place on farms, as students apprentice themselves to practising farmers and 'learn by doing'. Only recently have formal educational programs emerged as important in the Nordic region as part of the university and technical school system. Most learning opportunities in the United States of America (USA) are still found on farms or in special apprenticeship programs on some university or college campuses.

The term 'ecological agriculture' is commonly used in some countries in the Nordic region, and is used here to designate organic farming and gardening. The term 'organic' is widely used elsewhere in Europe and in most English speaking countries. In this chapter the terms are used interchangeably.

This Chapter begins with an overview of ecological farming and considers the place of education within it. Focusing primarily on the goals and structure of courses and curricula in the academic environment, our own experience as a small group of educators in setting up course units and programs in the Nordic region and in the USA is presented. Important questions related to agricultural education are considered, and the chapter concludes not with a recipe for a program in organic agriculture, but with a set of perspectives considered useful for the conceptual and structural changes needed towards designing an appropriate learning landscape for organic agriculture. The term 'course' is used here to denote a course unit, and is also called a 'subject' in some situations.

Overview of organic farming and education

Evaluation of educational opportunities needs to be made in the context of the growing organic food production and marketing sector. In Europe, the annual growth in organic farming areas ranges from 10% to 30%, depending on the country (Dabbert *et al.* 2004). In terms of area,

Table 16.1 Percentage of organic retail food sales as a portion of total food sales in 2000 (after Dabbert *et al.* 2004)

Country	%
Austria	2.0
Denmark	3.0
France	1.0
Germany	1.5
Italy	1.0
Netherlands	1.0
Sweden	1.0
Switzerland	2.5
United Kingdom	1.0

Austria has the highest current percentage of land in organic production at 10%. Denmark has the highest level of organic food in the marketplace at 3%, and among the other Nordic countries, Sweden and Finland produce a 1% share of organic food. The percentage of retail sales of organic food as a part of total food sales in selected countries are shown in Table 16.1.

Some sectors in agriculture have much higher rates of production and sales. For example, in Denmark the market share for organic oats was 27.2% and for organic milk was 23.5% in 2002 (GfK Danmark 2003). A survey in 2001 showed that only 10% of Danish consumers never purchased organic foods (Wier *et al.* 2005). Although the current levels of organic food sales in the USA are moderate at 1.0% to 1.5%, this segment of the marketplace has been growing at 20% per year for the past 20 years (Sooby 2003). While the organic food sector was traditionally dominated by small and local processing and distributing companies, now there is strong interest in the organic food business from larger and multinational corporations. Since 1985 there has been a major transfer of ownership from the local and regional companies to the multinationals (Hendrickson *et al.* 2001), along with the trend towards an industrial mode in the organic food sector whereby large scale, specialised, globalised and decontextualised technical and logistical solutions are commonplace. Support for increased education from the national political levels reflects this increase in importance in the marketplace and in large corporations.

Acceptance of this change has been much less rapid in our educational institutions, where the focus continues to be on the development of, and more efficient use of, technology, and improving the efficiency of the industrial model of agriculture. The industrial model assumes that labour and land are the most limiting factors to production, and that substitution of capital for labour is more important than exploring ecological efficiency in production, and far more important than finding the systems that are most socially viable. In the universities, there is a strong adherence to traditional disciplines and specialised research and teaching. The move from single disciplines to systems approaches, such as the study of whole-farm systems and multifunctional landscapes, continues to be a slow conversion process and is not a priority for most of our agricultural science colleagues (Langer *et al.* 2006). In addition to the challenges concerning methodological orientation, organic farming has often been discriminated against as being an ideology and not lending itself to scientific research. Fortunately, a more pragmatic attitude among scientists is becoming dominant along with increased availability of research funding to develop organic practices. The effectiveness of the consolidated research effort in Denmark through the Danish Research Centre for Organic Farming (DARCOF) since 1995 and the recent creation of the International Society of Organic Agriculture Research should help change attitudes within academic circles.

On-farm apprenticeship programs have been more rapid to respond to the interest in organic food production and marketing. Numerous examples of farmer-organised training opportunities exist in the Nordic region, in other parts of Europe and in the USA. Trygve Sund has welcomed apprentices to his biodynamic farm near Stange, Norway, for the last 30 years, and has trained over 250 young people in the methods and systems appropriate to that type of organic farming (pers. comm. 2004). In Finland, the Otava Agricultural College in Mikkeli, where the Helsinki University organic food and farming educational program takes place, converted the college farm to organic production in order to allow the students an opportunity for hands-on experience in practical organic farming. In the USA, the University of California at Santa Cruz, though not an agricultural university, has run apprenticeship programs since 1970, primarily because of demand from the local community, and this program attracts more than 100 applicants each year for only 40 spaces (pers. comm. 2004). The organic farm at the University of Maine has a community supported agriculture (CSA) entirely administered by students and sells organic produce to people in the community. Likewise, the University of California at Davis has a student organic farm located on campus. In the case of Maine, the practical program is closely connected to on-campus academic courses, while in California these programs are not directly connected to the teaching of mainstream agriculture. Only in recent years are new programs in agroecology and organic farming coming into the core university curriculum.

Emerging university programs and resistance to change

In the Nordic region, the NOVA University Network program in agroecology and ecological agriculture is a model for the integration of the study of organic agriculture into the university curriculum. In later sections, courses within several universities are described, along with the experiential methods that are considered important to learning. The introduction of such courses of study and curricula into mainstream universities and agricultural colleges is proving difficult, partly because of shrinking student enrolment generally in agriculture-related studies and tight budgets, but more importantly because there is still a strong adherence to traditional and narrow fields of study that are defined by classical offerings in agriculture. This is then reflected in the difficulty of fitting interdisciplinary, systems-oriented programs within the discipline-based structure of faculties and educational programs and in the general attitude of academics.

The commonly observed reluctance among university colleagues to move outside the established discipline boundaries is associated with fears of risk to their professional careers in terms of less recognition of their work by peers, perceived difficulty in getting research on agricultural systems published, and reduced potential for obtaining funding. This situation has been resolved to a small degree in the USA by the availability of research and education funding for sustainable agriculture projects, such as the *Sustainable Agriculture Research and Education* program (Berton 1998), and in the Nordic region with availability of national funding as well as regional and European Union (EU) grants.

In spite of this funding, there is a continuing trend in agricultural universities towards education and research in two new but totally different directions:

1 basic biochemistry and molecular biology with the goal of designing higher yielding crops and animals for the future; and
2 conservation biology and ecology with a focus on natural systems and preservation of biodiversity and the environment.

Both paths foster even more disciplinary specialisation, with fewer faculty members showing interest in broader perspectives and visions. The net result is an increasing divergence and accentuation of the conflicts already existing between conservation and the productive use of agricultural land and forest, rather than focusing on a collaborative study leading to the development of multifunctional rural landscapes. Within the production stream too, the links between production, processing, marketing and consumption necessary for an understanding of sustainable food systems is being ignored.

The proposal here is to have individual course units in ecological agriculture and agroecology at the very least. Beyond this, a broader and more integrated curriculum is needed to make students more aware of open, interactive, evolving and dynamic farming and food systems. Agroecosystems are more complex than the collection of their mechanical and biological components. To achieve better awareness by students, the emphasis in new courses is on experiential learning. The 'Hawkesbury Experience' emanating from Australia since the early 1980s and the innovations in 'systems agriculture' curricula have been inspirational and instructive to many educators designing courses in ecological agriculture (Bawden *et al*. 1984, 2000). Instead of focusing on the structure and content of single courses offered at the university, another approach is to concentrate on providing meaningful learning experiences, which move the learners closer to the real world and confront challenges comparable to what they will come across as graduate agroecologists (Lieblein *et al*. 2004). Examples and case studies are drawn from organic agriculture and food systems. The focus is on students and their learning, rather than on professors and teaching. The *process* of learning is at least as important as the specific course *content*, therefore experiential ways that allow learning to take place are adopted in preference to the traditional offering of lectures aimed at knowledge transfer.

When these components are developed as part of an integrated learning landscape, the new educational environment often may be poorly understood by some colleagues in academia, and seen by others as a threat to the establishment. Introducing many simultaneous changes in courses and plans of study is often the reason for this perception of threat among academic colleagues and students (Francis *et al*. 2001). It can also be a source of discomfort to students unaccustomed to taking responsibility for their own education. One way to overcome the resistance would be to initiate a totally experiential program rather than tinker with parts of it, and then manage the process of transformation with faculty and students, the feasibility of which was demonstrated at Hawkesbury in the 1980s (Bawden 2000). However, the ideal circumstances that would enable such elaborate academic experiments have become increasingly rare. In proposing a new field of study called agroecology, we envisage an approach and a program of study substantially different from conventional programs in agriculture and land management, but quite feasible within the institutional and economic structures of a contemporary university or college. The educational model being developed in agroecology and ecological agriculture in the Nordic region and parts of the USA has important implications for agricultural education in general, and is certainly not confined to organic agriculture. In the same way, research and education in organic practices and systems, and their adoption by a small but growing fraction of farmers, is providing new directions to conventional farming, although this impact is difficult to measure.

How ongoing research informs education

An important principle in the design of organic farming education is the reliance on both science-based and experience-based knowledge, and recognition of the role of values in setting goals for development. Those in agricultural science recognise explicitly the importance of technology and applications of the scientific method of testing alternative practices and systems. Many people applaud the development of organic systems that are friendlier to the environment than current conventional agricultural systems. However, even if the Fisher statistics are adequate for analysing the effects of one or two factors, they are weak in the evaluation of multifactor changes, and especially in the analysis of whole systems. Choosing appropriate indicators of system performance brings in further complications, when the need for multiple evaluation criteria beyond crop yields and single-season net economic returns is embraced. For example, when the impact of systems on the environment, long-term sustainability of yields and income, and distribution of benefits from agricultural production are included, it becomes essential to consider new systems assessment criteria and methods to simultaneously evaluate their impacts on alternative system performance. A detailed analysis that includes such a wide range of factors provides the challenge of internalising as many costs as possible in the system and looking at long-term sustainability. For example, to evaluate the contributions of a multifunctional rural landscape to society, beyond the production of food and fibre, it is important to identify and especially to quantify the most meaningful indicators of system performance and success.

In addition to conventional scientific research approaches, the importance of practical experience of farmers in providing an additional base of information for ecological agriculture systems design is recognised. The recognition of local and experience-based knowledge also leads to applications in participatory research methods. Development work in some countries over recent decades has highlighted the need to understand farmers' worldviews and has led to the emergence of participation as a key feature of a farming systems approaches to research and extension.

Methods from the social sciences are useful for collecting and evaluating information on performance and decision making, leading to the design of alternative systems. Such experience-derived methods and results are included in the educational process. Use of surveys, focus groups, personal interviews with farmers and applied projects in the conversion process from conventional to organic systems are among the research techniques that can supplement our conventional repertoire of biological and economic science methods. Students from agricultural science with little prior experience in social science methods often find these research techniques valuable in helping explain facets of their results and conclusions, and understanding the social relevance of their research. This has been an important dimension of the NOVA University PhD courses held in Norway (Lieblein *et al.* 1999). These dimensions of agricultural research are important to learning about integrated systems, not only to organic farming. Such methods help prepare the agroecologist who finishes the educational program to move directly into the professional world (Lieblein *et al.* 2004). An additional benefit from this mode of research is increased understanding and respect for the rationale, values and goals of the farmers and other participants in farming and food systems.

A breakdown of rural communities has taken place in the Nordic region. In Finland, for example, in their '100-hectare loneliness', the remaining farm families now run their mechanised farms in an industrial mode. As recently as 20 years ago, there were rural communities with an average farm size of 10 ha. With fewer farms and a reduced rural population, there is loss of infrastructure and services for those who remain, further accelerating the move to urban areas. The overall situation adds external cost to the farming and food sectors, but often the cost is borne by society in the form of subsidies from the federal government or the EU, or they are passed on to future generations.

A similar example is found in the industrialised agriculture in the USA's Midwest. There is continuing consolidation of farms into larger economic units and less reliance on the local economy and community, a prime example of an agricultural system whose negative social impacts will be felt. With a median farmer age of 58 years, over half of the farmers are likely to retire within the next decade. It is difficult for a young farmer to begin on a large scale, and thus most are excluded from the opportunity to enter agriculture. Most land that comes available will be purchased or leased by existing farmers with very large operations. At the same time, there is a concentration of wealth and power in the agricultural input industry and in the marketing of commodities and products from agriculture. There is a continuing move toward vertical integration, especially in the livestock sector, and an objective to control the product and the profits from the field all the way to the final sale in the supermarket.

Changes in both the input and the commodity marketing sectors represent a move toward homogeneity and an industrial model that defies ecological common sense and does not contribute to a sustainable future food system for society. It is essential that our educational process be designed to guide students in an objective evaluation of current systems as well as alternative future systems, to provide them with the tools and perspective to learn about the long-term impacts of decisions today that will shape tomorrow's agriculture and food systems. This dimension of learning includes the clarification of attitudes about research and education, and the development of a capacity for visioning the future, both important dimensions of education that must accompany the accumulation of more knowledge and new skills at the university.

Experiential learning

In developing courses, implementing educational programs, and observing students sharing new experiences along with the instructors, the process of learning is as important as the specific subject matter. Along with the expert view on pedagogy, it is the authors' experience that even if learning styles differ, many adult learners thrive on practical examples and hands-on experience, and that a fruitful learning process is exploratory and constructive (Mezirow 1991). Our educational programs have been organised around the principles of experiential or action education as first described by Dewey (1933), and developed into a practical model by Kolb (1984). The incorporation of systems thinking to this experiential model, particularly from the constructivist position of seeing farming and such other 'soft' systems as human constructs, makes it a strong and relevant paradigm of education.

One of the assumptions implicit in this paradigm shift is that students arrive at courses in agroecology with an extensive background in other courses, as well as lives rich with outside experiences. The challenge for the educator then is to add to those experiences and provide a learning landscape where students are encouraged to share their expertise with others in the learning community and to integrate new knowledge into what they already have. The main goals are to add value to their existing knowledge and to help develop abilities in critical thinking and decision making. The new knowledge and skills enable students to process disparate and often conflicting facts and experiences into an integrated appreciation of agricultural and food production systems.

To implement such a program requires some adjustment in the attitudes of instructors toward their roles in the learning process, often in sharp contrast to their prior experience in the educational system. The emphasis needs to change from teaching to learning. To make the transition from perceived expert ('the sage on the stage') to an effective catalyst for learning ('the guide on the side') may be more of a change than some are prepared to make. To allow students to assume responsibility for their own learning also may be difficult, if instructors have been trained to believe that they are always responsible for everything that goes on in the classroom and the field. It takes personal confidence on the part of the instructor to assume this different type of role in the educational process, one that Østergaard and Lieblein have called a 'pedagogy without mercy' (Lieblein and Østergaard 2001), when we transfer some degree of power to students and cannot predict what challenges that will provide us. These approaches have worked well for us in the agroecology programs in Norway and in the Midwest of USA.

A perspective that could help in changing focus from teaching to learning could be illustrated by the formula: knowledge = information × processing

The process of 'processing' encompasses the mental activities of taking in information, reflecting on it, interpreting and integrating it within an existing framework. When there is zero information or zero processing, there is zero knowledge. This perspective could open up different ways to look on the information that the instructor will find relevant for students. Different kinds of information could be included, and could be delivered in several ways, but probably not only as lectures that give no time for processing. This approach puts greater focus on the reflection and assimilation skills for information processing, and this could be a key to developing activities in the curriculum.

Among the methods that seem successful in achieving relevant processing are the problem-oriented and project-based learning and case-study approaches that take students out of the classroom and into the real world to face similar challenges to those they will confront on the job. Our design of courses to meet the needs of students has begun to focus on the knowledge, skills, attitudes and capacity to future scenario building; the essential competencies to be developed by students as they 'become agroecologists' (Lieblein *et al*. 2004).

Programs and courses in organic farming and agroecology

As different models are being used to provide education in organic agriculture, it is important to describe the complementarities between agroecology and organic agriculture as understood in the Nordic region. Agroecology is chosen for the title of courses that embrace systems thinking, experiential learning and holistic approaches to the study of farming systems and food systems. The term is seen as a useful umbrella that accommodates relevant disciplines and permits us to integrate these in contextual learning situations. Because of the personal and professional interests of individuals or groups in the agroecology discipline, organic systems are often used as examples and models to illustrate the importance of holistic thinking, designing for complexity and resilience in systems, and considering the efficiency of the complete human food cycle. Examples of courses that add to the already rich diversity in current university course offerings are described briefly here, recognising that efforts to build organic agriculture education are on the rise today, especially in Europe. A brief explanation of educational programs in several European countries is provided in Box 16.1. This section offers ideas to those looking for models to base their efforts in course design, as well as serving as a preamble for the future design of learning landscapes for agroecology and ecological agriculture.

Denmark

Formal courses in organic agriculture at the Royal Veterinary and Agricultural University (Den Kongelige Veterinær-og Landbohøjskole, KVL) were first offered in 1988, coinciding with the expansion of the organic sector in the country. 'Ecological agriculture' was the title of a popular 12 European Credit Transfer System (ECTS) points course (30 ECTS being equivalent to one semester of full-time at Masters level). Under the free choice option available to Danish students, there were as many as 80 students taking this course in the early 1990s. Group-based project work and interdisciplinary learning were hallmarks of this course and students worked with real-life conversion plans for farms undergoing change towards organic farming for their projects. Global perspectives and values orientation have been important features of the course. In later years, based on the demand for a BSc level course for students requiring only an overview of organic agriculture, a new six ECTS point course 'Introduction to ecological agriculture' was commenced in 1998. Both courses were offered in Danish by faculty members of the Organic Farming Unit. Declining student demand, introduction of

Box 16.1 An overview of educational initiatives in ecological agriculture in selected countries in Europe

The first university courses in ecological agriculture in Europe were started in 1982 at the University of Kassel, Witzenhausen (Germany) and at Wageningen Agricultural University (the Netherlands), where professorships in ecological agriculture had been established. During the mid-1980s, single courses in ecological agriculture were started in several European universities. In many places these courses have evolved into programs, of which an overview is presented here.

Network approach

A popular European-wide 'common degree level specialisation in ecological agriculture' at the Bachelor level has been running for close to a decade under the EU's Socrates program. The Royal Veterinary and Agricultural University (Den Kongelige Veterinær- og Landbohøjskole, KVL) in Denmark; University of Wales, Aberystwyth; Wageningen University, Swedish University of Agricultural Sciences, Uppsala; University of Kassel, Witzenhausen, Institut Superieur d'Agriculture Rhones-Alpes, France; University of Tuscia, Viterbo, Italy; Agricultural University of Norway, Ås, and Helsinki University, Finland, have been the main partners in this consortium. The consortium was reorganised into the *European Network of Organic Agriculture University Teachers* in 2003. It now includes universities in Slovenia, Poland, Austria, Hungary and Portugal. The Network's website, where all relevant information concerning institutions, contact people and course offers are given (ENOAT 2004).

A three-year pilot project, Learning through Exchange – Agriculture, Food Systems and Environment (LEAFSE) is being led by the KVL in Denmark with three other European partners (Wageningen University, University of Wales, Aberystwyth and University of Kassel) and four Australian partner universities, University of Queensland (St Lucia and Gatton, Queensland), University of New England (Armidale, New South Wales), University of Western Australia, (Perth, Western Australia) and University of Western Sydney (Richmond, New South Wales). This project has organic farming as the focal point of a one semester exchange study at MSc level.

Programs at the Bachelor and Master level

Austria. University of Natural Resources and Applied Life Sciences, Vienna, offers a two-year Master of Science (MSc) in organic farming.

France. Beginning in 2004, the FESIA group of five engineering universities in agriculture and the food industry offer a two-year specialisation in agroecology.

Germany. University of Kassel, Faculty of Organic Agriculture Sciences at Witzenhausen, has a three-year program in organic agriculture and a two-year MSc in international ecological agriculture.

Italy. The University of Turin offers a three-year Bachelor of Science (BSc) in organic farming. The University of Tuscia offers a three-year BSc in ecological agriculture. The two, in collaboration with FESIA and the Agricultural University of Norway, also offer a two-year international MSc in agroecology.

Slovenia. The University of Maribor offers a two-year MSc program in organic production and Improvement of alternative crops.

The Netherlands. Wageningen University offers a three-year BSc program and a two-year MSc- program in organic agriculture.

Wales. University of Wales, Aberystwyth, offers a BSc in organic agriculture and a Postgraduate Certificate in Organic Farming.

more interdisciplinary course options in the agriculture curriculum and the recent restructuring of the entire program have meant that these two courses were not offered in 2004.

'Ecological agriculture 1' is the title of an international course on offer at KVL under the Socrates Common European Degree level specialisation in ecological agriculture. It is a 24 ECTS full semester course that fits the descriptions for a thematic course at the Danish agricultural university. The aim of the course is to give students an understanding of the basis of ecological agriculture from an integrated viewpoint. Ecological farming in Denmark is given consideration followed by themes related to biodiversity, cropping system design and the technological aspects of organic farming. A three-day study tour and other one-day excursions into the farming areas of Denmark enable the predominantly international students to gain a good understanding of the state of organic farming in Denmark. Fifty per cent of the course assessment is based on a group project, 20% on literature evaluation, and the balance on the basis of a description of individual learning outcomes by the students.

Finland

The courses at the Helsinki University in Mikkeli make up a 70 ECTS program that aims to give an overview of organic farming and food systems, create understanding and develop skills towards sustainability according to its underlying principles. All the courses are interdisciplinary and participatory and include the ecological, economic and social points of view. Excluding the optional literature-based courses, all courses have a study component which includes interaction with farms, other organic enterprises or food systems as an essential starting point for learning. One course (LUOMU 1 Organic agriculture) focuses on farming systems, another (LUOMU 2 Organic food industry) on the rest of the food chain, while the remaining courses deal with the whole food system, including the value dimensions (LUOMU 0.1 Introduction to organic food and farming, LUOMU 3 A Readings, LUOMU 4 Practical training, LUOMU 5 Organic quality, LUOMU 6 Organic food systems, LUOMU 7 Case study, LUOMU 8 C Readings and LUOMU 9 Practical training in a research group). Courses with numerical identification from 1 to 4 are Bachelor level courses and the rest are Masters level courses.

The emphasis in these courses is on progressive inquiry learning (Hakkarainen *et al*. 2004) with the focus on the learning process rather than on teaching specific content. Students set their own learning goals and share expertise among themselves. As examples of interaction with the practice besides lectures, discussions and readings, in LUOMU 1, students become familiar with eight farms, in LUOMU 2 several other enterprises, and in LUOMU 6 they work with one food system in the neighbourhood in a multidisciplinary student team. They complete a series of exercises based on cases that include an analysis of sustainability and reasoned proposals for further development. In LUOMU 4, students have 40 days of practical work on organic farms or in other enterprises such as those trading or marketing in organic food, and restaurants, and then prepare an analytical report on the experience. They add value to the experiential field activity by analysing and evaluating their observations and putting this into a logical framework in the report. In LUOMU 7, multidisciplinary student teams take a systems approach to evaluating a case in developing an organic farming and food system and report this as a tutored research project.

Sweden

Three courses have been designed at the Swedish University of Agricultural Science (Sveriges Lantbruksuniversitet, SLU) to address theory, project management and systems research methodologies. Although organic farming is not in the title, the courses often use organic farms for the case studies in the field. The course 'Adaptive management – Theory' considers assessment methods for sustainable land use within a framework of systems ecology. Students examine the concept of sustainability, define general systems principles and review evaluation methods for sustainable development and land use. 'Adaptive management – Project' comprises group work using available measurement tools and indicators with a client case in the field. Students propose different development scenarios and recommend potential improvements in the current situation and context of the farm. 'Systems ecology – Analysis tools' has the goal of enriching the discourse on sustainable land use by using emergy accounting and its implications for the environment and the economy (Odum 1996). Students learn emergy systems language, major flows and transformations, relationship of money to emergy, natural systems and simulation using models.

Norway

An intensive semester at the Norwegian Agricultural University includes two courses – 'Agroecology and farming systems (PAE 302)' and 'Agroecology and food systems (PAE 303)' – where students work on issues with clients in the rural landscape and communities. Each course begins with a three-day experience visiting farms and communities to provide context and preliminary information, both in production and economics as well as in the ecological reality and social integration of people in the landscape. This is followed by lectures and discussion, intermixed with library research and meetings among the teams and faculty. Student groups formulate questions and indicators for measuring what they observe in the field and the community. They become familiar in the research in specific technical fields, the available technologies and the information resources that are appropriate to their location. The final reports or client documents are presented to faculty, students and farmers for evaluation. The intensive semester just described with its two courses has been envisioned as the compulsory beginning for those choosing to complete a two-year MSc program in agroecology at the Nordic universities. The semester in 2005 was open to students from other regions with an interest in ecological agriculture at the Masters level.

United States of America

The most comprehensive resource listing on education and training is the website compiled by the Alternative Farming Systems Information Center (AFSIC 2005), which is operated by the United States Department of Agriculture. The site includes both formal courses offered by colleges and universities, and practical internships and apprenticeships available and advertised by non-profit groups and individual farmers. There are many more opportunities provided by farmers, but these are not publicly advertised and can be found by consulting with the grassroots groups in sustainable agriculture around the country.

Many of the courses in organic farming have evolved from earlier courses designed around the topics of sustainable agriculture and agroecology (Altieri and Francis 1992). Most courses are taught at the upper division or graduate study levels, and assume a general basic understanding of the science of agriculture, and build on prior courses in soils, crop management, crop protection, agricultural economics and sometimes ecology. The textbooks used are most commonly those of Altieri (1995) or Gliessman (1998). Organic systems are examples of farming strategies that incorporate many ecological design principles, with multiple goals of production efficiency, acceptable economic returns, a benign impact on the immediate environment and social viability. Local food systems are commonly used as a positive alternative to the growing global food chain.

Some courses focus primarily on the biogeochemical cycles and production details, whereas others introduce a stronger emphasis on farm and local community economics, as well as the environmental and social implications of alternative production systems. There is some agreement that agroecology should deal with the widest possible range of biological, economic, social factors and implications of the farming and food system – agroecology could be defined as the 'ecology of food systems' (Francis *et al*. 2003).

'Science-based organic farming and gardening (AGRO 496/896)' at University of Nebraska – Lincoln is designed to explore both the scientific basis of organic practices and integrated systems as well as the experiential foundation of organic farming from farmers' viewpoint. A reading list covers the history of organic farming, current practices in management and alternative marketing systems. The core activity of the course is a series of classes on theory and then meetings with farmers, processing and marketing specialists, and an organic certification supervisor who each describe their application of the combination of science and experience in organic farming and food systems design. Each student reports on one book on history or the current management of organic production systems. A major exercise for the term is each student's development of a draft extension guide, either related to a specific topic such as control of thrips in organic onion and garlic or dealing with a general topic such as certification rules or alternative marketing schemes. A reference developed for this course as well as for extension meetings with farmers and advisers is available on the web (cari.unl.edu/organichandbook2004.doc). Two comprehensive and key resources are the website of the Applied Technology Transfer to Rural Areas (ATTRA 2006), and the newly published curriculum and teachers' guide from the University of California, Santa Cruz (Miles and Brown 2003). 'Agroecosystems analysis (AGRO 436/836)' is a summer travel course with students from Nebraska, Iowa, Minnesota, and other states. There is precourse reading on the context of the region, and then students and faculty come together for eight days of intense travel with interviews on ten farms with the farmers and families. Student teams design indicators for farm evaluation, and need to establish their criteria for evaluation, including production, economic, environmental and social dimensions and impacts of the farming systems. Written team reports and individual learner documents are used to assess the educational process (Wiedenhoeft *et al*. 2003). The course reading materials include Rickerl and Francis (2004) from the American Society of Agronomy.

Development of a curriculum

To date, most of our emphasis has been on development of individual course units or foundation building blocks needed in organic farming and agroecology. These courses help prepare students to deal with the complexity and uncertainty they will face in working for sustainable agriculture and food systems. Less attention has been paid in our work to the design of an overall curriculum. Existing course units have been built on in the study guides in specific and important disciplines, and others have been added such as the integrative options listed in the previous section. These courses in ecological agriculture can add value to component knowledge and skills gained from prior experience and current courses. The educational landscape will be improved by focusing on who is being educated, and what the emerging agroecologist is expected to do with their education and experience in the program when they graduate (Lieblein *et al*. 2004).

The thinking so far has been constrained to some extent by modelling an educational program with a sequence of courses that resembles other curricula in the university, and thus fits into current schedules and is acceptable to the decision makers and peers on the university evaluation committees. This is a logical first step to getting a course of study approved within the contemporary university educational structure, yet whether this model is the most appropriate one for designing education in agroecology and ecological agriculture is being questioned. Reference has already been made to the case of the University of Western Sydney, Hawkesbury, where an innovative and complete redesign of agricultural curriculum was successfully made already in the 1980s. Yet, structural and financial changes in university education and the need for conformity have forced this program to regress towards retaining only a fraction of its original design, the entire process being described recently by its leader as a 'cautionary tale' (Bawden 2000).

One opportunity for change in the curriculum is to challenge the sequence of courses in a student's plan of study, and question the belief in a 'one size fits all' approach. The suggestion of 'just-in-time education' compels the pattern of courses in the undergraduate curriculum to be examined and to see where each fits in a logical continuum of acquiring knowledge and skills to become a successful professional (Salomonsson *et al*. 2005). In contrast to the courses designed only for the accumulation of more knowledge and practice of additional skills, it is important also to include attitudes and visions for the future. When students are encouraged to examine their attitudes toward the subject matter and how new information and skills can be applied to real world situations, they can become enthusiastic and even passionate about the topic and are able to translate their feelings into action. There is often a greater gap between knowledge and action than between ignorance and knowledge (Lieblein *et al*. 2004), and the properly designed educational curriculum can help to narrow that gap and provide stimulus toward appropriate action. Further, it is important to build skills for visioning and long-term planning, a step that prepares students to confront questions that have not yet been asked. These capacities of students are not encouraged in a lecture situation, in which the instructor becomes the major source of new information and the evaluation is based on students' capacity to feed back answers on exams. The change in educational paradigm suggested here can be challenging to professors as well as to students, each of whom may have grown up in a different educational culture. The goal is to build on the concept of 'everyone a teacher, everyone a learner' in designing new educational curricula in agroecology and ecological agriculture (Francis and Carter 2000).

Two models can be used to illustrate the differences between our current agricultural universities that are designed around conventional departments and specialised activities and a possible future active learning university. The current paradigm (Figure 16.1) has specialists organised in departments around classical disciplines. The primary communication is among

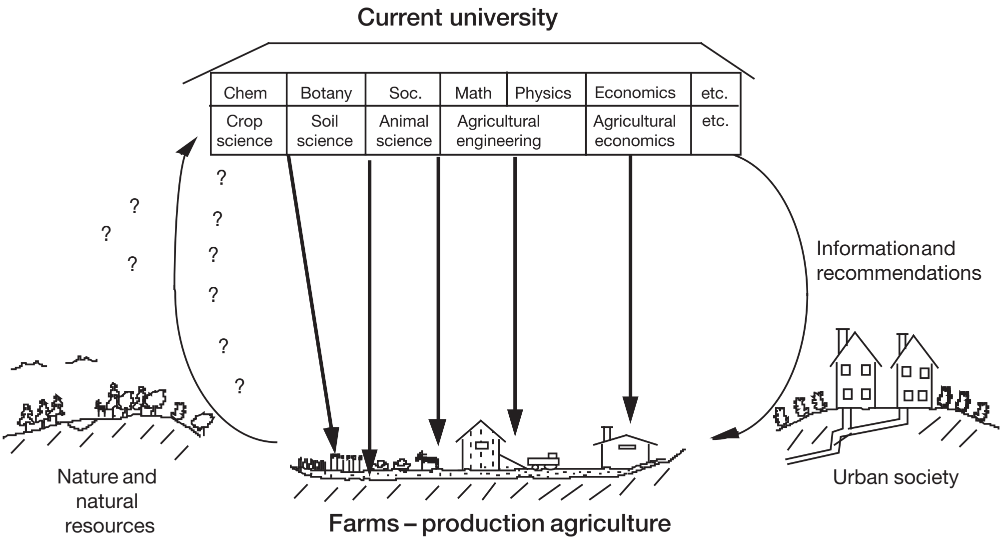

Figure 16.1 Current structure of an agricultural university, including the limited relationships among departments, one-way transfer of information to clients in the landscape, and disconnection between natural areas and farming areas and urban society (from Lieblein *et al*. 2000).

those within each department, and each of them reaches out to the public with specific recommendations on new crop cultivars, or fertiliser recommendations, or how to manage weeds. There is minimal feedback from the clients because after all, it is assumed that the experts reside in the university and have access to the latest information. There is a disconnection in our minds between the natural environment that is studied by natural resource specialists with little interest in agricultural production, and the crop and animal management specialists who work in the agricultural production areas. Parallel to this, there is a complete disconnection between the people working in food production and those in urban society, the latter with all their challenges of securing an adequate food supply, finding energy and meeting the needs of a culture that is divorced from both the natural environment and farming enterprises. Students learn all of their theory in the university, and later face the challenge of confronting the complexity and uncertainty of the real world, and often are fearful of even entering that world. They may seek employment within their personal comfort zones rather than adapt to an unknown and seemingly hostile agricultural sector that is even sceptical of the skills that they have to offer. Although this is an extreme example, it does illustrate some of the challenges faced in a specialised society.

The alternative vision presented in Figure 16.2 for a future active learning university has specialists, but they are organised in large, interdisciplinary departments in flexible teams that are fluid and responsive to new challenges in society. There is frequent and two-way communication between those who work in the university and those in society. The landscape is a continuum from areas of nature through production areas to the urban areas, and the interfaces between them are indistinct and complementary. Students take some of their basic sciences and humanities in the university campus, while having some practical experience to ground their classes in the reality of the human situation in food production and consumption. In the upper level courses they move freely out of the university and back in to acquire more resources and skills, but most of their education takes place in the social and production landscape where they will eventually work. They are organised in teams that include various specialists, and all become familiar with the tools, skills and vocabulary needed to work in interdisciplinary teams. The learning stays centred on a series of projects that reflect current problems or challenges in natural areas, production systems or the urban part of the food system and materials cycle. The emphasis is on teamwork, practical problem solving, working with clients and becoming an action-oriented professional ready to take a place in this same environment.

This latter model is an idealised organisation that is perceived by us to be flexible, and with potential to meet current needs as well as to adjust to those of tomorrow. This model will be discussed in more detail in the final section. This model is not only most appropriate for study of organic farming and food systems, but also relevant to more general application across the specialties of the post-modern university.

Key information resources

In the search for relevant information that will be most useful for understanding and designing new organic agricultural systems, instructors and students need to look beyond the traditional libraries, lectures and Internet resources explored in our universities. Much of the science that has been developed is available in these conventional locations, and a large part of what has been published is applicable to organic as well as conventional agricultural systems. However, a wider information resource exists that should be used for study of organic production systems in agriculture. As described above, much of the information in organic farming is available from farmers who have accumulated this expertise through years of practical experience, and

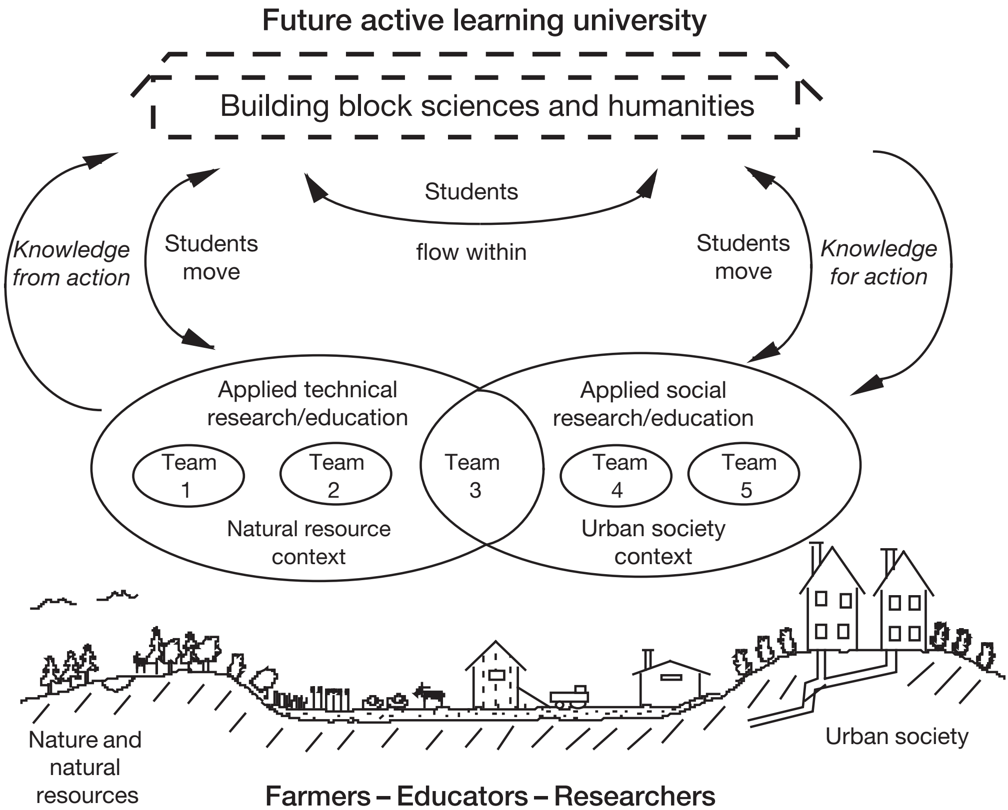

Figure 16.2 Structure of a future active learning agricultural university, including maximal communication among faculty in different disciplines, two-way exchange of information with clients in the landscape, and close connections between natural areas and farming areas and urban society (from Lieblein *et al.* 2000).

the adaptation of crops and practices to their specific locations and farming systems. Most of this is not available in libraries or on the Internet.

One method for acquiring this experience is to invite farmers to the university classroom. Along with pictures of their operations, farmers can present practices and systems and explain them together with descriptions of the farms where they are applied. This is a cost-effective way to capture the ideas and cumulative experiences of farmers and bring these to large groups of students on campus. We quickly learn from the presentations of farmers that their systems are location specific to the climate and weather, soils and topography and economic resources and goals of each farm family. This is in stark contrast to the conventional industrial paradigm of standardisation of practices, with chemical applications and other technologies to homogenise the production environment. In organic farming, there is no 'one size fits all' set of practices that will optimise the situation for any individual farm family.

An even better approach to learning is to take students off campus to the farm and to the food industry. At these locations, the total experience of seeing, feeling, smelling, hearing, and tasting the flavour of the farm can be offered to the learners, at the same time as absorbing knowledge and even developing hands-on skills in the farm's operation. When describing a rotation of crops or a stacked enterprise system of grazing, it is far more meaningful to be standing in the field or walking the pasture while hearing the farmer describe the system. Such an environment encourages questions and stimulates discussion of the practices and systems, as well as opening issues far beyond the field boundaries. This is extremely difficult to re-create in the classroom and is not possible without immersing students in some way in the field or in the community.

Farmers are often more than willing to share their farms and experiences in this way. The challenge for educators is to identify the resources needed to transport and sustain students in the field and to compensate farmers for their time, as well as to convince administrators that this type of education is worth the trouble and expense. This is far less efficient in terms of accumulated student credit hours that can be counted by the department and credited to a professor, compared to the large lecture environment. It is only when effective long-term learning is measured that the benefits of such a system can be fully appreciated.

One concern of educators in organic farming and sustainable agricultural systems is the availability of adequate textbooks, journal articles, and other resources for giving students the foundation needed for in-depth study, writing class papers and backstopping their field research with sufficient and relevant information. Much of the information resides in the 'grey literature' of conference proceedings, annual reports of non-profit or farmer organisations, and in the heads of farmers who are practicing these systems. One approach to collecting and making this alternative information available is to encourage authors to publish their experiences. *Our Sustainable Future* is a book series from Nebraska Press that covers topics from soil organic matter (Magdoff 1992), to whole farm systems (Bender 1994), to regional concerns about natural resources (Opie 1990), to global concerns such as green plans (Johnson 1995) or the impacts of Chernobyl (Yaroshinskaya 1995). This active series continues to publish two to four projects each year.

Technical journals are also available in which articles from scientists cover topics related to sustainable agriculture and organic farming. Among these are the *American Journal of Alternative Agriculture* (begun in 1986, with the new title of *Renewable Agriculture and Food Systems*), *Biological Agriculture and Horticulture* (begun in 1982), *Journal of Sustainable Agriculture* (begun in 1990), *International Journal of Agricultural Sustainability* (begun in 2003), *Agriculture, Ecosystems and Environment* (begun in 1974) and *Agricultural Systems* (begun in 1976). Proceedings of the biennial scientific congresses of the International Federation of Organic Agriculture Movements (IFOAM) publish conference presentations in all aspects of organic agriculture. Regular international journals in agricultural science occasionally carry scientific papers covering organic agriculture, particularly in plant and animal sciences. The social, political and economic aspects of organic agriculture and agrifood systems have been hotly discussed since about 1995 in journals such as *Agriculture and Human Values*, *Socialia Ruralis* and *Rural Sociology*.

Much of the most relevant information continues to appear in newsletters from non-profit research centres, annual reports of small projects working in organic agriculture, and bulletins from specialised organisations such as the Organic Farming Research Foundation. The Organic Eprints archive has been developed by DARCOF since 2002. A German language version of this much used service is supported by the Forschungsinstitut für biologischen Landbau (Research Institute of Organic Agriculture) in Switzerland (see also *Chapter 15*).

Future perspectives in designing educational programs

It would be presumptuous for anyone to believe that they could foresee the future and design learning programs that would be appropriate for unknown conditions and challenges. But just as it is proposed that students learn to develop their capacity for envisioning alternatives for the future, educators must put themselves to the same task in the design of future learning landscapes. The following scenarios and fundamental components of learning systems are presented in the hope of stimulating discussion and encouraging others to ask the 'what if' question with respect to possible learning approaches and their impacts on future graduates.

New models for experiential learning

Most of the thinking about future learning models is based on experience within the current system and university organisation. New courses have been suggested, curricula modified, and enrichment activities set up on the farm and in the community while clinging to the conventional system of credit points, class schedules in well-defined semesters and a time expected from the start of study to graduation. This constrained thinking is probably a reasonable approach to selling the study of organic farming within the existing agricultural universities and faculties, because models that are too far removed from current reality would be seen as completely unacceptable. But in designing new models, should we not ask such questions as to how and why courses should be organised into semesters, when the growing cycles of crops and seasonal care of animals is more closely related to the annual climatic cycles in each place? Is it more effective to study three to five subjects simultaneously during each semester, or should we adopt a modular system of full time study of a series of topics that are arranged in logical sequence? Or are some topics such as a foreign language best learned with full-time immersion while others need time for reflection and practice between sessions and thus are best learned in the current system of courses? What is the relative weight that should be placed on basic humanities and sciences versus the practical study of real-world applications of this knowledge? Shall we, as natural scientists, take the research from pedagogy seriously and make explicit applications of this body of knowledge, or shall we continue to use our own working hypotheses and experience in course design? How do we build on the current knowledge and skills of each individual student as they enter the educational environment rather than setting up rigid requirements that all must complete – as if there were no individual differences in preparation? How do we organise ourselves and our teaching to optimise scarce resources, perhaps in a university structure similar to that shown in Figure 16.1? How do we assess success in learning? These are all questions we should ask if we are serious about designing structures that can promote experiential learning.

Just-in-time education

Should chemistry be taught in the first year of university? To begin the argument, most university-level students today have already studied the elements of chemistry in at least one course in the secondary school, and therefore have a basic understanding of chemical reactions and the elements that make up the complex physical world. It is assumed that it is so important to keep building on this knowledge of chemistry, even though many students appear to not understand why such study is important. It has been observed at SLU in Sweden that many students delay taking the chemistry course until their final year, perhaps because only then can they appreciate its importance or because it is the final requirement for graduation. It is asked, why not build the relevance and an appropriate context for each subject such as chemistry so that students arriving to the class are highly motivated to learn, because they have already seen where this can be applied and realise that they need the knowledge about to be acquired? This could be called 'just-in-time education' and a more elaborate discussion is provided in Salomonsson *et al.* (2005).

Expanding the learning community and environment

Many kinds of information are needed by students as they build their personal libraries of skills, facts and experiences. Some of these can be found in university classes and many come from their activities outside the classroom. The fact that students do not find time to adequately prepare for classes, to do a high quality job of writing their outside essays or to integrate information from prior classes into the applications in a new context is often bemoaned by teachers. Perhaps there should be exploration of how to expand and extend the learning environment beyond the spatial walls of the classroom and the temporal walls of a specific 50-minute lecture/discussion.

One step is to recognise that not all information, knowledge or wisdom is contained in the university library and faculty. Expanding the notion of faculty to include people with special talents or skills from farming, from government, from non-profit groups and from business could enrich our classroom or field trip learning environment, even when these people do not share our academic qualifications. The focus should be what people have to offer our students, and less on their degrees on the wall. Another question is how to effectively extend the structured or directed learning experience beyond the classroom walls and into the rest of the student's day and evening. How do we foment discussion and analysis of critical issues as students interact with peers, family and other instructors during the other 110 waking hours of the week when they are not in lectures? Can we plant compelling questions, or ask for results of an opinion survey, or otherwise extend the engagement with the material beyond our allotted time? These are challenges and questions that should be tackled with enthusiasm and creativity, recognising that students spend far more time with their friends and on outside jobs than they do with us in class.

Developing the learning landscape

The learning landscape includes the design of the learning environment within the university. If students perceive that subject X is the main topic for a lecture each Monday, Wednesday and Friday from 10:00 am to 10:50 am and has little relevance in their lives any other time of the week, they are unlikely to learn much about subject X no matter what we do in the lecture. If there are assignments outside of class and adequate rewards for completing them, challenges that can become a part of their regular conversations with peers, or applications of information in their jobs or in other courses, there is more likelihood that students will internalise and apply the lessons rather than memorising a few facts just before the examination.

If the total learning environment can be designed so that subjects X, Y and Z in a given semester are complementary and interdependent, that a given broad assignment will receive credit in both classes Y and Z, or that integration of information from all three classes is essential in order for them to pass all of the classes, there will be greater incentive to embrace and assimilate the information and put it to use. If there is a relationship of subject Y to the part-time job that keeps students in the university, there will be further incentive to use the knowledge and skills gained in that subject. If subject Z can be related to a burning issue, such as a food scare, a coming election or a proposed city ordinance that will directly affect students, there is ample opportunity and motivation for conversation to continue outside the class and a chance to gather more information and opinions to enrich the learning experience. Our creative thinking can be used to implement these possibilities.

Integration of learning with local communities

The concepts of 'service learning' and 'engaged universities' have come into the educational lexicon in recent years. The possibility to volunteer with service organisations, to shadow potential employers or to contribute in numerous ways to the community can broaden the learning experience and give students contacts in the real world that could be useful later. In 2003 an environmental art project in Lincoln, Nebraska, was initiated with secondary school students acting as teachers and resource people for elementary students: both groups found the activity highly valuable, and two of the older students are now seriously considering teaching careers. Thus, we can tap into the people and resources of the local community to further the learning agenda, and can also find ways for students to contribute to the community while learning with the experience.

Education and learning with farmers as teachers and as clients

Elevating the status of farmers, organic or conventional, to that of teachers can help to recognise and reward their relevant experience, and the most articulate farmers can help design and guide a learning environment in agriculture. While they are interacting with students while being instructors, farmers can serve as sounding boards for questions and proposed solutions to improving the present situation as students formulate ideas and look for potential implications. Often a thoughtful farmer will be able to ask such questions as, 'Have you thought about this angle? What will be the costs and benefits of this change? What will happen if conditions change? Do you think that this would help me meet my long-term goals for the farm?' Putting farmers in this role helps to validate their experience, and give them more status in the eyes of the student who will soon have these same farmers as clients or cooperators (see *Chapter 17*).

Teachers' contact with the world of agriculture

As recently as 25 years ago, most university and college instructors in agriculture had prior practical experience in owning or managing farms. They were comfortable with the context and the language, and often continued to control some land from their own families and work their way through the same decisions each year that were facing their farmer clients. This situation has changed drastically, as most newly hired professors in agriculture come from the city with little or no personal practical experience in farming, and today many have not lived in the rural landscape or small community. Such a change can make a tremendous difference in the way that instructors approach their classes and how they make use of outside resource persons to support their classes or organise study tours for their students. When they are not confident, themselves, in confronting the stakeholders, it is difficult or impossible to pass such confidence on to students. Some type of experience is needed to provide at least a flavour of the farm and rural community life to teachers, realising that people are busy and have many other obligations on their time.

Organisation of universities for effective agriculture education

With much of the relevant information residing outside the library and the immediate campus community, it is valuable to think of how we can design a learning landscape and the incentives for students to seek the most relevant information. Farmers in the classroom, short field tours to farms or summer travel courses such as the one described above in relation to the Agroecosystems analysis course (AGRO 436/836) can all provide vehicles for putting students in touch with reality. The proposed future learning university (see Figure 16.2) provides ideas about how one could structure the physical plan and the multiplicity of activities that take place there and in the landscape and community to meet the broad and practical and educational goals.

Beyond farming systems and towards food systems

The goal of organic farming was always compatible with those of sustainable development. When organic farming was conceived as a concept and a practice, in the 1920s–1930s, our societies were still dominated by rural life and most people lived close to most of their food sources. The debate in agriculture at that time was therefore focused on farming practices, which were rapidly changing through the increasing use of mineral fertiliser and pesticides (Figure 16.3A).

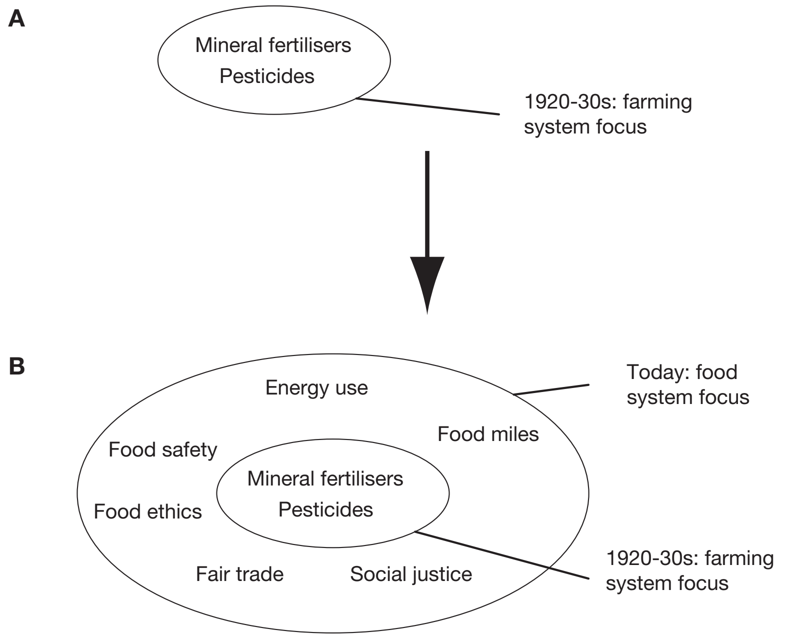

Figure 16.3 Changes in the focus of farming systems management from (A) the 1920s to the 1930s to (B) the situation today.

A new range of challenges has appeared on the agricultural scene. Important new areas are energy use, not only in farming practices but the energy used to transport food, often across continents; the whole issue of a fair trade with food, not only between developing and industrialised countries but also between various industrialised countries competing in a globalised economy; other social justice issues and food safety and food ethics, including animal welfare (Figure 16.3B).

If ecological agriculture still has the ambition of having sustainable development as a goal, it needs to embrace all these new areas. It is therefore important that education in ecological agriculture takes on the wider food system dimension.

Conclusions

Based on the authors' experience in teaching organic farming in several universities, and on the development of graduate courses and an MSc degree in agroecology in the Nordic region, there is much to learn about education in this emerging arena. Much of the past and current education and training has taken place in apprentice-type situations with farmers as teachers and young people as learners in a practical, hands-on learning environment. Some of this experience is being captured and joined with theory as courses are developed in organic agriculture in the universities. This is a process not easily followed in most universities, since there is much doubt about the importance of organic methods and systems in the agricultural mainstream.

Along with specific methods for plant protection and maintaining soil fertility, the authors are using experiential learning methods for the study of organic farming. Accepting farmers and others from the food industry as experts who have valuable information for students both in the classroom and the field, the concept of 'faculty' is thus expanded. In a time of restricted budgets, it is a challenge to reimburse these people for their time and to mobilise students off the campus to other sites in the learning landscape. These learning methods are incorporated into new courses as well as emerging sections of a future curriculum in agroecology and sustainable agriculture.

Other dimensions of future learning approaches for organic farming include just-in-time education, the scheduling of courses and activities that are sequenced in the program for times when students are prepared and recognise the need for each subject. Learning off-campus in projects that deal with real-world situations gives students confidence in their ability to handle complexity and change, both characteristics of the farming and food sector. Finally, it is conceptualised how a future active learning university might be structured to support all these innovations. There needs to be a careful examination of disciplines and departments, campus and off-campus facilities and mobility of students, and how to catalyse the active learning process.

In this Chapter, our description of current activities in education in organic farming has moved well beyond a listing of topics and courses offered by our universities in the Nordic region and the USA. It is essential to confront the educational system and ask if it is set up optimally to prepare students for work in the farming and food systems of the future. Some structural changes are needed in how to organise courses, curricula and universities and how to think about education. Organic agriculture and agroecology, as addressed by small groups of educators in agriculture, provide one example of how these changes could be achieved in the university as part of a broader learning landscape.

References

AFSIC 2005. *Educational and Training Opportunities in Sustainable Agriculture*. Alternative Farming Systems Information Center, United States Department of Agriculture , Beltsville. <http://www.nal.usda.gov/afsic/AFSIC_pubs/edtr.htm>. Accessed 17/1/06.

Altieri, M.A. 1995. *Agroecology: the Science of Sustainable Agriculture*. Westview Press, Boulder, Colorado, USA.

Altieri, M.A. and Francis, C.A. 1992. Incorporating agroecology into the conventional agricultural curriculum. *American Journal of Alternative Agriculture* 7(1–2): 89–93.

ATTRA [Appropriate Technology Transfer for Rural Areas] 2006. *ATTRA – National Sustainable Agriculture Information Service*. ATTRA – National Sustainable Agriculture Information Service, Fayetteville. <http://www.attra.org>. Accessed 17/1/06.

Bawden, R.J. 2000. The cautionary tale of the Hawkesbury experience: a case study of reform in agricultural education. In: van den Bor, W., Holen, P., Wals, A.E.J. and Filho, W. (eds) *Integrating Concepts of Sustainability into Education for Agriculture and Rural Development*. Peter Lang Scientific Publishers, Frankfurt. pp. 289–304.

Bawden, R.J., Macadam, R.D., Packham, R. and Valentine, I. 1984. Systems thinking and practice in the education of agriculturists. *Agricultural Systems* 13: 205–225

Bawden, R.J., Packham, R., Macadam, R. and McKenzie, B. 2000. *Back to the Future: Reflections from Hawkesbury*. In: Cerf, M., Gibbon, D., Hubert, B., Ison, R., Jiggins J., Paine, M., Proost, J. and Röling, N. (eds) *Cow up a Tree: Knowing and Learning for Change in Agriculture – Case Studies from Industrialised Countries*. L'institut National de la Recherche Agronomique (INRA), Paris. pp. 397–409.

Bender, J. 1994. *Future Harvest: Pesticide–Free Farming*. Nebraska Press, Lincoln.

Berton, V. 1998. *Ten Years of SARE: a Decade of Program, Partnerships and Progress in Sustainable Agriculture Research and Education*. Sustainable Agriculture Research and Education (SARE) Program, United States Department of Agriculture, Washington DC.

Dabbert, S., Häring, A.M. and Zanoli, R. 2004. *Organic Farming: Policies and Prospects*. Zed Books, London.

Dewey, J. 1933. *How We Think. A Restatement of the Relation of Reflective Thinking to the Educative Process*. D.C. Heath, Boston.

ENOAT 2004. *Welcome to ENOAT. European Network of Organic Agriculture University Teachers (ENOAT)*. Norwegian University of Life Sciences, Ås. <http://www.umb.no/?viewID=7187>. Accessed 17/1/06.

Francis, C., Lieblein, G., Gliessman, S., Breland, T.A., Creamer, N., Harwood, R., Salomonsson, L., Helenius, J., Rickerl, D., Salvador, R., Wiedenhoeft, M., Simmons, S., Allen, P., Altieri, M., Flora, C. and Poincelot, R. 2003. Agroecology: the ecology of food systems. *Journal of Sustainable Agriculture* 22(3): 99–118.

Francis, C.A. and Carter, H.C. 2000. Participatory education for sustainable agriculture: everyone a teacher, everyone a learner. *Journal of Sustainable Agriculture* 18(1): 71–83.

Francis, C.A., Lieblein, G., Helenius, J., Salomonsson, L., Olsen, H. and Porter, J. 2001. Challenges in designing ecological agriculture education: a Nordic perspective on change. *American Journal of Alternative Agriculture* 16(2): 89–95.

GfK Danmark. 2003. GfK *ConsumerScan, Den økologiske forbruger 2002, intern rapport udarbejdet for Økologiske Landsforening*. GfK Danmark, Frederiksberg.

Gliessman, S.R. 1998. *Agroecology: Ecological Processes in Sustainable Agriculture*. Ann Arbor Press, Chelsea.

Hakkarainen, K., Palonen, T., Paavola, S. and Lehtinen, E. 2004. *Communities of Networked Expertise: Professional and Educational Perspectives*. Elsevier, Amsterdam.

Hendrickson, M., Heffernan, W.D., Howard, P.H. and Heffernan J.B. 2001: *Consolidation in Food Retailing and Dairy: Implications for Farmers and Consumers in a Global Food System. Report to the National Farmers Union, January 8, 2001*. Department of Rural Sociology, University of Missouri, Columbia.

Johnson, H.D. 1995. *Green Plans: Greenprint for Sustainability*. Nebraska Press, Lincoln.

Kolb, D. 1984. *Experiential Learning: Experience as a Source of Learning and Development*. Prentice Hall, New Jersey.

Langer, V., Rasmussen, J. and Francis, C. 2006. Narrow focus of MSc and PhD agricultural research in Denmark, US and Canada. *Journal of Sustainable Agriculture*. In press.

Lieblein, G. and Østergaard, E. 2001. *Shifting Focus – Experiences from the First NOVA MSc in Agroecology*. Department of Horticulture and Crop Sciences, Program for Pedagogics, Universitetet for miljø-og biovitenskap, Ås.

Lieblein, G., Francis, C.A., Salomonsson, L. and Sriskandarajah, N. 1999. Ecological agriculture research: increasing competence through PhD courses. *Journal of Agricultural Education and Extension* 6(1): 31–46.

Lieblein, G., Francis, C. and King, J. 2000. Conceptual framework for structuring future agricultural colleges and universities. *Journal of Agricultural Education and Extension* 6: 213–222.

Lieblein, G., Østergaard, E. and Francis, C. 2004. Becoming an agroecologist through action education. *International Journal of Agricultural Sustainability* 2(3): 147–153.

Magdoff, F. 1992. *Building Soils for Better Crops: Organic Matter Management*. Nebraska Press, Lincoln.

Mezirow, J. 1991. *Fostering Critical Reflection in Adulthood: A guide to Transformative and Emancipatory Learning*. Jossey-Bass Publishers, San Francisco.

Miles, A. and Brown, M. (eds) 2003. *Teaching Organic Farming and Gardening: Resources for Instructors*. Center for Agroecology and Sustainable Food Systems, University of California, Santa Cruz. <ucsc.edu/casfs/training/manuals/tofg/index.html>. Accessed 17/1/06.

Odum, H.T. 1996. *Environmental Accounting. Emergy and Environmental Decision Making*. John Wiley and Sons, New York.

Opie, J. 1990. *Ogallala: Water for a Dry Land*. Nebraska Press, Lincoln.

Rickerl, D. and Francis, C. (eds) 2004. *Agroecosystems Analysis*. American Society of Agronomy, Madison.

Salomonsson, L., Francis, C.A., Lieblein, G. and Furugren, B. 2005. Just-in-Time Education. *NACTA Journal* 49(4): 5–13.

Sooby, J. 2003. *State of the States*. Organic Farming Research Foundation, Santa Cruz.

Wiedenhoeft, M., Simmons, S., Salvador, R., McAndrews, G., Francis, C., King, J. and Hole, D. 2003. Agroecosystems analysis from the grass roots: a multidimensional experiential learning course. *Journal of Natural Resource and Life Science Education* 32: 73–79.

Wier, M., Andersen, L.M. and Millock, K. 2005. Information provision, consumer perceptions and values – the case of organic foods. In: Russell, C. and Krarup, S. (eds) *Environment, Information and Consumer Behaviour*. Edward Elgar Publishers, Cheltenham. pp. 161–178.

Yaroshinskaya, A. 1995. *Chernobyl: the Forbidden Truth*. Nebraska Press, Lincoln.

Chapter 17

Design of farmer education and training in organic agriculture

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Introduction

Organic farming and food systems continue to grow throughout the world, stimulated in part by increasing consumer concerns about food safety and security. Although the rapid growth of the 1990s has slowed, there is an emerging awareness of multiple values such as protection of environmental quality and enhancing local identity (Hubert *et al.* 2000). Dabbert *et al.* (2004) report that organic food now represents from 1% (Sweden, France) to as much as 3% (Austria, Denmark) of retail food sales. Sales continue to grow at 10% to 30% per year. The growing importance of organics in the food system is rapidly attracting the attention of multinational food companies that are moving into this lucrative business (Buck *et al.* 1997).

Organic agriculture was initiated as a social movement in which both farmers and consumers had an active role. Later, increasing concerns about the environment resulted in the growth of organic agriculture. Today in the European Union (EU) and United States of America (USA), official organic regulations shape organic farming practices. Organic farming is also strongly influenced by conventional agriculture and by society at large. For instance, food scares may rapidly increase the demand for organic products. Yet the multiple mechanisms that affect product quality are complex and interactive, and it is difficult to isolate simple indicators in food systems. Publicity about single events (e.g. the McLeod [2004] study that found more toxins in organic baby foods than in corresponding conventional ones) can cause drastic trends or reactions in the marketplace. Consumer preferences and other societal factors may rapidly bring new challenges for organic agriculture, such as the present introduction of genetically modified organism (GMO) varieties in conventional agriculture that cannot be contained due to pollen drift and product mixing. Education and training should help organic farmers to find flexible methods to deal with rapid changes in crop choice and to understand how production practices affect product quality.

Only limited attention has been given by the private agricultural adviser system, the federal farmer support system, or the public Cooperative Extension System (USA) to farmers seeking information on organic farming. There are national and EU support funds available for the conversion from conventional to organic production systems, but there is still limited infrastructure in place to provide relevant information for farmers. In this void, the organic farmer organisations and certification groups have provided assistance in education and training. However, much of what is available is quickly assembled and has little basis in adult education and learning theories. An example is the program for organic farmers in Nebraska Cooperative Extension (Francis *et al*. 2004), with information developed almost entirely from empirical experience.

In general, organic farmers' educational needs differ substantially from those of conventional farmers. This is because of the special characteristics of organic agriculture, its activist origin as a social movement and recent rapid development, and its complexity, diversity and location specificity of production systems. Therefore, organic farming is considered to be a knowledge-intensive endeavour rather than a traditional way of farming. Although there are some similar questions and problems for both conventional and organic farmers, organic farmers face particular challenges that require specific information and specially designed education and training.

In this Chapter the unique characteristics and challenges of organic agriculture are explored and discussed. These challenges need to be understood for developing both the content and methods of efficient education for organic farmers (Seppänen 2002). Three different perspectives for learning are presented: knowledge acquisition, participation and knowledge creation (Hakkarainen *et al*. 2004), and related to farmer training in organic agriculture. Concrete examples from planning and conducting networks and educational programs and using learning tools are presented. Some elements of these case examples are discussed in the context of the three learning perspectives. The application of this theory enables reflection, assessment and improvement of the quality of our educational methods and strategies. The knowledge-creation perspective seems especially important for organic farming. This Chapter ends with a general discussion and conclusion about farmer education and training in organic agriculture.

Characteristics and challenges of organic farming

Activism and dynamic change

Organic agriculture developed as a social movement based on and involving joint efforts by many different interests: farmers, consumers and traders, as well as scientists and ordinary citizens (Michelsen 2001a). The first underpinning principles (Woodward and Vogtmann 2004) were:

1 the concept of a farm as a living organism, tending toward a closed system but responsive and adapted to its own environment;
2 the concept of soil fertility through a *living soil* that has the capacity to influence and transmit health through the food chain to plants, animals and humans; and
3 the notion of a whole system with a dynamic interplay among its parts and within its environment.

Organic agriculture advocates and practitioners showed a strong desire to change some parts of conventional agriculture, and thus they were considered to be critical of certain elements of mainstream agriculture (Michelsen 2001a). Although organic agriculture is now being institutionalised as part of agricultural policies and regulated by national and international legislation, many scholars see that organic agriculture still maintains its own value-based, movement kind of activism (Goodman 1999, Vos 2000, Kirschenmann 2000). Michelsen (2001b) studied the organic movement's desire for *self-regulation* and its possibilities in the regulated context of the EU. The activist character of organic agriculture is reflected in the social relationships organic farmers have with extension specialists, inspectors, researchers and consumers (Michelsen 2001b, Seppänen 2004). This has important implications for training and education.

Together with institutionalisation during the 1990s, environmental concerns have increased in significance in organic agriculture and changed its character, especially in the EU. In

Finland, for example, society at the national level emphasises environmental aspects of agriculture in conventional as well as organic systems. This is true of the EU countries in general, where subsidies promote environmental awareness and compliance with resource-conserving practices, and conventional agriculture has adopted many environmentally friendly practices. In some ways, organic farming has served as an example in this process. There has been a substantial influence of organic farming methods on the mainstream of agriculture, though it has not been able to quantify this observation. The early organic principles just cited and the later environmental aspects are important societal motives of organic agriculture (Seppänen 2004). They show that organic farming is dynamically changing in time, and this change needs to be considered in farmer education.

There is often a considerable overlap between what is written about organic production and programs of research and education in sustainable agriculture (Edwards *et al.* 1990, Francis *et al.* 1990, Hatfield and Karlen 1994). Similar philosophy is shared by those writing about and teaching agroecology (Altieri 1995, Gliessman 1998, Lieblein *et al.* 1999). A broader and more inclusive agenda for research and education is emerging with the definition of agroecology as the *ecology of food systems* (Francis *et al.* 2003). In this Chapter it is recognised explicitly that just because a system is organic, it is not necessarily sustainable, and therefore environmental aspects and sustainability issues should be taken up in training of organic farmers. Organic farmers also need to relate closely with processors and marketers, and understand intimately the desires of consumers – especially if one goal is direct marketing.

Diversity and location specificity

Compared to conventional agriculture, organic farms are more diverse enterprises, often have integration of crops and animal enterprises, depend more on non-chemical inputs and careful use of internal and renewable resources and market through niche channels. There is a complexity in managing organic crop/animal systems that requires more information and skills. For example, a farmer with a typical maize–soybean rotation in Nebraska requires knowledge about two crops, each planted in monoculture in a given year. In contrast, an organic farmer must plan a longer-term rotation that may involve not only a cereal–legume sequence but also summer crops rotated with winter crops and annuals in rotation with perennials. The latter systems likely include rotation of annual cereals with several years of mixed swards of pastures. A well-designed organic system may include a complex combination of different crops in strips through the fields, relay plantings or other mixtures of species, close interactions with border areas left in native vegetation and annual/perennial agroforestry patterns.

The creation of multiple managed biotopes within an organic field and the immediate proximity presents a complexity in management decisions that is vastly unlike conventional systems. Due to the requirement for crop rotation, intensive biological soil management, and access of livestock to outside areas, organic farms are by definition more complex, thus decision making on farming and marketing practices is more difficult. Compared to conventional agriculture, farming decisions and activities in the organic system involve many more factors, and because of their complexity, the decision making process may appear less linear and seemingly less rational than what is followed by conventional farmers. The brief list of questions below that are high priority for a farmer planning for the coming cropping season illustrate the different levels of complexity in conventional and organic systems (Table 17.1).

Design of an educational program for each group of clients will be different. For the conventional farmers, a list of products and prices plus the latest experimental results on their efficacy will often suffice. Although some questions on specific products and information from other growers could be useful, there is minimal need for discussion or processing information, and much of the same information could be gleaned from a publication or website. In

Table 17.1 Comparison of questions asked by conventional farmers with two crop species and organic farmers with biodiverse crop–animal systems

Typical question	Conventional farm	Organic farm
Which crop cultivars to plant?	What are the highest yield maize and soybean cultivars under optimum conditions?	Which cultivars of ten crop species produce the most sustainable yields of quality products for sale?
What planting system should I use?	Can I maintain current row width, optimum dates of sowing for maximum yield?	How do many crops fit together in the field and optimise labour use?
What soil fertility program should I follow this year?	Where can I locate the cheapest form and source of N, P, K and starter fertiliser?	How can I design long-term rotations to include legumes, compost, cereals, and pasture?
What plant protection methods should I use?	What are the latest GMO cultivars and cheapest sources of chemicals?	Can I design an integrated pest management strategy using biodiversity of field and surroundings?

contrast, the organic clients often learn through interactive discussions with networks of farmers and researchers, place high value on the social capital of the group and have to make complex decisions based on these interactions. They require all the same information as conventional farmers on seed varieties and potential cultural practices (minus the chemicals), but must apply this knowledge and use their skills to manage a highly diverse biological system in which they are continually adjusting to changes in weather and conditions of the crops. Although the general goals of organic farmers may remain constant through the season and across years, the adaptive methods of reaching these goals may be in constant revision and adaptation to current realities.

Farmers using organic and sustainable farming strategies most often strive to maximise the specific adaptation of cultivars, practices and systems to fit the unique niches in each field and even subareas of fields. This is another type of site-specific management, dependent on observations and critical thinking skills of the farmer as well as information gathered from other organic farmers in similar situations. Diversity and location specificity make organic agriculture knowledge intensive. In the following section we turn to three perspectives of learning which are used as bases for studying and developing knowledge-intensive activities.

Perspectives for learning

Sfard (1998) originally described knowledge acquisition and participation as different metaphors for learning. More recently, Hakkarainen *et al*. (2004) examine three basic perspectives on, or approaches to, learning:

1 knowledge acquisition;
2 participation; and
3 knowledge-creation.

These three perspectives provide a conceptual framework for learning that may guide us in improving the quality of training and education. These three perspectives are used and modified for the purpose of farmer training in organic agriculture.

The acquisition perspective understands learning as a process of transmitting knowledge to an individual learner. An individual student's mind is seen as a container, and learning is a process that fills the empty vessel with knowledge. The traditional form of agricultural exten-

Table 17.2 Three perspectives of learning (after Hakkarainen et al. 2004)

	Knowledge acquisition	Participation	Knowledge creation
Main focus	Adoption of subject-matter knowledge	Participation in social communities, enculturation	Methods and practices of knowledge formation, discovery and innovation
Theoretical foundations	Didactic theories and theories of knowledge structures	Situated and distributed cognition, some sociocultural theories	Activity theory, knowledge creating organisations and knowledge-building theory
Unit of analysis	Individuals	Communities, networks, cultures	Activity systems, networks, knowledge building communities

sion, a transfer of technology (TOT) model, is one illustration of this perspective. It assumes pre-given knowledge structures that the learner is instructed to assimilate.

An alternative perspective is participation, a process that emphasises the role of social communities. Learning is viewed as participation within the context of shared activities. Through participation, people learn to become full members of a community, and simultaneously develop and reshape their identities. Knowledge, according to this view, does not exist as such in the world or only in the individual's mind; rather it is one dimension of participation in a culture in different ways (Hakkarainen *et al*. 2004).

Although both of the previous perspectives may include certain innovative elements, neither of them focuses on the creation and development of knowledge. Therefore, Hakkarainen *et al*. (2004) introduce the perspective of knowledge creation. Its aim is both to create new knowledge and to develop corresponding social practices. In this process, the existing knowledge is essentially enriched or shaped (as summarised in Table 17.2).

Hakkarainen *et al*. (2004) see that all three perspectives are necessary for understanding learning and the authors think all three can be used in designing education. Each has strengths and weaknesses. Knowledge acquisition is most often applied in agricultural extension and education, and many conventional extension programs in Nebraska are very much like classroom lectures, including the PowerPoint© presentations. Most field tours are actually lectures in the field. In organic agriculture education and training, this approach can help build our farmers' knowledge base. Information may include basic ecological principles of nutrient mineralisation, adaptation of varieties, appropriate pest management for organic systems or details on new regulations and requirements.

As the review in this Chapter of characteristics and challenges in organic farming suggests, the acquisition of ready-made knowledge is likely to be insufficient for learning organic agriculture. The participation perspective has importance in organic farming in terms of activism, which means that organic farmers often have a need to take part in different communities and networks that support this way of farming. The participation perspective views a workshop or a training session as an opportunity for building social communities and cultural identities. This implies that it is often good to cooperate with farmers in planning education and training. Participation perspective is also involved in hands-on training such as on-farm trials or other types of material experimentation.

Organic farms often require diverse and appropriate solutions that are location specific, and organic agriculture needs to face many challenges in a dynamic way. Therefore, the authors suggest that knowledge creation is a necessary perspective for learning in organic agriculture. The knowledge-creation paradigm requires that there are deliberate efforts to extend current knowledge. Theoretical and generalised knowledge of researchers and extension workers can be used together with the local experience about each field and farm supplied by farmers for collectively finding relevant solutions, which in turn can be tested and further developed on other fields and farm. Farmers are learning in order to apply the information in their own practical work. Therefore, it is useful to start from the questions and challenges farmers face in their activities, which forms a good ground for knowledge creation. It is important to pay attention to farmers and their needs, and to create suitable learning tools in training (Seppänen 2002). These can be tables, figures, measurement devices and hands-on activities, and often many of them are needed. Visions or models or other types of presentations of the state-of-the-art practices, or activities that help farmers to articulate their desired goals, can facilitate the knowledge-creation process. Explicit goals are among the most important parts of designing farming systems, yet one of the most difficult to articulate (Savory 1999). A case example that applies such a visionary tool is included [see *Using a learning tool in organic vegetable farming (Finland)*]. Tools can also be words and concepts that help us better understand different phenomena. It is essential to focus on the knowledge-creation process itself rather than to focus only on the end results. Networks that illustrate the principles of dispersed leadership and empowerment of groups can be used to enhance both participation and knowledge creation.

The three perspectives have different roles in designing farmer education. Knowledge acquisition is necessary for complementing the knowledge base. With participation, learning may be seen as a process in which new organic farmers gradually become full members of the organic agriculture community (Lave and Wenger 1991). Organic farming is a dynamic activity that is continuously evolving; perhaps the biggest challenge in organic agriculture is not only learning about the existing techniques and practices but also learning how to develop them further by reshaping them or creating new ones. This can be achieved through knowledge creation. Farmers' efforts in developing new practices and techniques are an important resource for organic agriculture. Networking and involving various participants is important in knowledge creation.

Using a learning tool in organic vegetable farming (Finland)

In a recent activity-theoretical study, a framework (Figure 17.1) was created for understanding and analysing the learning challenges in Finnish organic vegetable farming. Activity theory is a theoretical approach that originates from psychology that emphasises the mediated, collective and evolving nature of human activities (see Engeström 1987, Chaicklin *et al.* 1999).The development of the framework has been documented and discussed elsewhere (Seppänen 2002, Seppänen 2004). It is described here how the learning tool was used in an educational workshop for organic vegetable farmers.

The framework (Figure 17.1) serves for visualising and categorising farmers' choices in farming practices, illustrating organic farming in an evolutionary and developmental way. A specific crop, or system, or activity on a farm can be charted at one point on the horizontal axis (use of natural resources). Farmers can compare their practices with those of other farmers on this visual chart, using this learning tool to evaluate their own practices and meanings.

On the vertical axis, the tool suggests that farming practices somehow link the farm with other stakeholders in the rest of society. For instance, buying commercial organic inputs links the farm with business enterprises, while fodder–manure exchange makes a linkage with other farms. Similarly, different choices in farming practices and ways of farming may imply contacts with different information resources.

The learning tool was used in farmer education in 1999–2000, in workshops organised by a regional rural advisory centre. As an example, one session with 14 farmers is described from notes taken after the workshops and materials used in education. The theme was the different

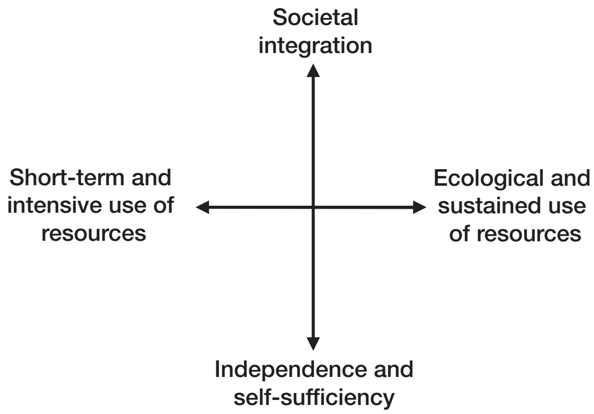

Figure 17.1 A framework and a potential learning tool for reflection in Finnish organic vegetable farming.

solutions that farmers have for designing their production and marketing operations so they will fit together efficiently. The main features of five organic vegetable farms were presented: short histories, acreage and field types, different crops, machinery, crop rotations, marketing channels and labour force. There were large and small, intensive and extensive farms, some selling to local markets with a broad repertoire of products and some having only two or three products for national wholesale markets. Participants were asked to place the five case study farms into appropriate quadrants of the model. The farms with intensive crop rotations raised a lot of discussion. While placing the farm in the model, participants also reinterpreted it and renamed the axes. The new tool with the five farms placed in the quadrants is shown in Figure 17.2.

What meaning did the participants derive from the model? The resource use dimension was best understood in terms of land use, which was observable in the crop rotations on each farm. Intensive rotations extract more in products sold to markets, while extensive crop rotations favour soil fertility, anticipatory handling of pests, and less nutrient leaching, which is the main environmental problem of Finnish agriculture. Extensive rotations are less risky

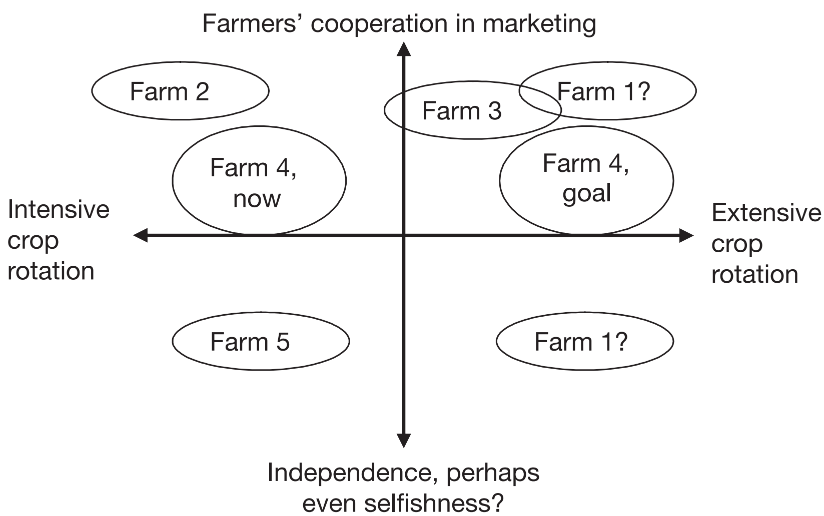

Figure 17.2 The learning tool interpreted and applied by the workshop participants.

but are also less profitable. The participants generally agreed on the importance of going towards ecological practices, but there were different opinions about which crop rotations should be categorised as intensive or extensive in the framework (Figure 17.2).

Additionally, the social or vertical dimension was mostly understood as farmer cooperation in marketing. Farms placed in the lower half had farmers unwilling to cooperate with other farmers in marketing their produce. Although Farm 1 was considered ecologically sound, there was some uncertainty regarding whether it belonged in the upper or lower quadrant on the right side of the model because several farmer-participants felt this farmer 'only listened to himself'.

Before the workshops, our impression was that orientation to customers would be an essential learning challenge for organic vegetable farmers. In contrast, the group brought forth relationships with other farmers in marketing and participation in farmers' marketing cooperatives as the key issues. The main challenge for this group was not customer orientation, but forming a unified group of organic vegetable farmers to work together on negotiations with customers, especially with the big wholesale markets. This indicated a desire to strengthen the community of organic vegetable farmers.

From our perspective today, the workshops were successful in illustrating and integrating several factors that are most often discussed in isolation, such as how natural resource use may be linked with farmers' social relations. It was important to discuss together the heterogeneity of crop rotations. In organic vegetable farming in Finland and probably also elsewhere, farmers do have a choice for intensifying their production and this option, together with the more diversity-supporting practices, should be considered and discussed in farmer training. Visionary learning tools may help farmers critically reflect and evaluate on different alternatives.

The case study farms were essential to make the tool understandable. The model was open and abstract enough so that the farmers could modify and use it for their own purposes. Still it was not totally the farmers' construction because the form and general dimensions were given. Use of the tool serves as an example of knowledge creation (Hakkarainen *et al.* 2004). The researcher's abstract model, concrete examples of case study farms and the needs of the participating farmers together produced new knowledge. However, whether this use of a learning tool as knowledge creation led to transformations in on-farm practices or in farmers' networking remains an open question. Knowledge-creation processes often require lengthy time periods. Not only farming practices but also farmers' social relations are often reshaped in knowledge-creation processes.

Networking in organising educational activities (Norway, USA)

There is a wide range of examples of how networking has been achieved by farmers, with and without the participation of government agencies and private advisers. Although not all dedicated to organic farms and farmers, these networks are descried as examples of how farmer-generated ideas have reached wide audiences in several places in the world.

Farmer variety testing circles in Norway

Since early in the history of plant improvement at the Agricultural University of Norway (NLH), there have been farmer circles in cereal-producing regions that took on responsibility for the final testing of new cultivars under commercial conditions. Often advised by the public sector plant breeders or by members who were themselves crop consultants, these circles increased seed and planted modest-sized commercial fields of promising new varieties. Primarily for their own benefit, but also for other cereal growers throughout the country, these farmers reported their results based on highly practical tests under the conditions of their current farming systems. This system continues today as a highly effective, grassroots method of on-farm testing of the value of new cereal cultivars. Some of these farmers use organic practices, and it is a valuable example of participatory networks in agriculture.

Practical Farmers of Iowa (PFI)

Founded in the mid-1980s, this farmer-organised group in the midwest of the USA has been highly effective in testing new technologies on the farm, bringing focus to innovative marketing systems and local food sales, and lobbying successfully for funding to initiate a high-profile sustainable agriculture centre at Iowa State University. Their long, replicated, drive-through plot designs have become widely accepted by farmer groups across the USA. This field testing method brings statistical credibility to on-farm research results. The most frequent experiments conducted by PFI have involved different levels of nitrogen fertiliser, use of starter fertiliser, methods of ridge tillage, alternative weed management options and long-term crop rotations. They have used multiple farm sites for the same experiment to add validity to the results. With widely publicised field days, a first-class newsletter, and recently initiated children's summer activity programs, the PFI has made a substantial and lasting contribution to the future of family farms in Iowa. Methods are described by Rzewnicki *et al.* (1988).

Nebraska on-farm fertiliser experiments

A project in the late 1980s financed by the state Department of Energy stimulated the authors to evaluate different nitrogen rates on cereals in continuous cultivation versus cereals following a legume. Farmers identified by county Extension Educators sat down with the project technician to decide on fertiliser rates and field plot design. Often treatments were based on the farmer's current fertility practices, plus additional rates that were 50 kg ha^{-1} above and 50 kg ha^{-1} below the current rate. The technician collected information during the growth of the crop, while the farmers generally conducted the harvest in close collaboration with project staff. As expected, there was much less response to applied fertiliser nitrogen in the rotation treatments, and at least a 50 kg ha^{-1} reduction in the recommendations for the next year's maize or sorghum crop. In some cases no additional nitrogen was recommended, a logical outcome of interest to organic farmers. One unique feature was the reporting of results to farmer groups in each county, where the results were analysed and then presented to the farmers at a meeting with no recommendations or conclusions. The farmers were asked to interpret the data and yield results, coming up with their own decisions for fertiliser application in future years. The technician, a soils specialist from the university, would eagerly answer questions about mechanisms or details of the trials when asked, but let the farmers carry the agenda through the recommendations and conclusions from the experiments (Franzluebbers *et al.* 1991, 1994).

Watershed-level planning in the midwest of the USA

A four-year grant from the federal Sustainable Agriculture Research and Education (SARE) program allowed the University of Nebraska and collaborators to plan and implement training from 1993 to 1997 across the North Central Region of the USA. Each workshop was planned and topics chosen by an interdisciplinary team of extension specialists in close consultation with the local educators and non-profit farmer and research groups in states where the workshop would be held. An attempt to make the learning methods systemic for future workshops included these steps:

- multiple agencies and groups worked together to plan the events;
- farmers were key participants in choosing topics and presenting tours;
- integration of topics was achieved by introductions and segues between topics; and
- continuous evaluation was used to assess learning and adjust the program.

Results of the first year's workshops were published in the *Journal of Sustainable Agriculture* (Francis and Carter 2001), and titles of the four workshops are indicative of the increasing spatial level of scale for each succeeding workshop:

- 1994: Everyone a Teacher, Everyone a Learner;
- 1995: Shared Leadership, Shared Responsibility;
- 1996: Linking People, Purpose, and Place: an Ecological Approach to Agriculture; and
- 1997: Facing a Watershed: Managing Profitable and Sustainable Landscapes in the 21st Century.

These extension workshops helped to set in motion the sustainable agriculture training programs in our individual states. The methods used were participatory and hands-on in the field where possible. Discussion and active learning was strongly encouraged throughout the programs. Groups in the host states that had previously not known each other found common ground and began to plan cooperative education programs. These were emergent properties, or unexpected successes, that were realised as a result of the SARE workshops in the USA. Many of the participants were exposed for the first time to successful organic farming operations during the workshops.

These practical examples of farmer education programs in the Nordic countries and the USA are all characterised by a high level of farmer participation, and by shifting ownership and decision making in the program to the farmer members of each group. Although they are not exclusively organic programs, they represent many examples of participatory networks, and these serve to illustrate the principles of dispersed leadership and empowerment of groups.

Discussion and conclusions

Organic production systems are complex out of necessity, since soil fertility and plant protection are provided by applying the principles of ecology and lessons from natural ecosystems. It is this complexity, in part, that makes the need for unique education and training opportunities so important for organic farmers. In addition, the lack of institutional support with information from universities and government agencies in most countries makes this a valuable area to explore and for which to seek appropriate educational options.

Based on the case studies described in Finland, Norway and the USA, the authors conclude that building networks of multiple agencies and groups, enhancing participation and using a variety of learning tools for discussion and reflection appear to be important strategies for organic farmers' training. These strategies will also provide potential for knowledge creation.

The participatory form of planning seems particularly appropriate for education and training for organic farmers, since there is a need to generate new knowledge by combining the experiences of farmers with the science developed by formal research projects. The power of such synergies has been described and illustrated by programs in several countries. The idea of combining theory with practice for knowledge advancement is being implemented through cooperative on-farm research activities, such as the cases in Iowa and Nebraska, USA. What the authors conclude from long experience with farmers and examining their information needs in organic farming, is that site and farm specificity is a large issue, and the homogenised types of practices being promoted in conventional agriculture are not appropriate for sustainable systems using organic techniques.

Based on experience, the authors see that current education and training for organic farmers is primarily focused on those scale-specific technologies that are appropriate to medium and small farms. However, industrial-sized organic farms also exist, especially in the USA, and choices of farming practices that are appropriate for these large-scale and intensive/

industrial farms are also available. Therefore, education and training should enhance farmers' critical reflection of alternative choices in terms of crop rotations and the diversity of farm operations. The complications and potentials of integrated crop–animal systems are cited by many organic farmers as both the basic foundation of designing an organic system, and one of the complicating factors in finding the optimum combination of enterprises and design for systems. In some cases there is a cropping practice by system interaction, and in many cases there is not. Therefore, education and training can help organic farmers be both open and critical to agricultural innovations.

Three perspectives of learning are described that help explain the basis of learning in the dynamic and knowledge-intensive domain of organic agriculture. Case studies from farmer workshops and educational programs were presented to trace elements that enhance participation and knowledge creation. Participation perspective views education of organic farmers as a way of enhancing the organic community. As the case with Finnish organic vegetable farmers suggests, the community-building aspect is important and should be considered in organic farmer education. Participatory learning is also involved in networking and in shifting ownership to various constituent groups, including farmers, in planning educational programs and workshops. Knowledge acquisition is most obvious through lectures and tours where subject matter knowledge is given, and has benefits in some situations. All these learning perspectives are ways of understanding learning rather than just applying ready-made educational strategies. Knowledge acquisition can also be integrated into participatory, interactive and creative educational activities.

Knowledge creation through interaction and combining experience with science around specific case situations is seen as the most powerful of the learning perspectives. It requires certain openness for new conclusions and recommendations to emerge, as in the case of farmers interpreting nitrogen rate figures in Nebraska, or Finnish farmers interpreting the visionary framework. According to Edvin Østergaard (1998), 'organic agriculture can be viewed as a workshop of ideas for the development of new knowledge and perspectives', and despite the increasingly standardised and regulated character of organic farming, education and training can offer space and resources for this knowledge creation (see Seppänen and Helenius 2004).

In the design of education and training for farmers, the authors do not suggest that the methods and perspectives described here are only for organic producers. They are good for the design of all education and training programs, but the need is greatest where systems and components are complex, and there are implications of the results and their application both on the farm and in the larger organic market and community of farmers.

It is essential that universities, ministries of agriculture, and other organisations serving farmer clients begin to show greater interest in education and training for organic farmers. Organisations have an important role in systematically collecting, testing and further developing the knowledge created in farmer workshops and networks. The interest for organic farming should start in the classroom, and the Nordic Regional Agroecology Programme illustrates how organic farming can be incorporated into graduate education (see *Chapter 16*). Organic farming education for students and for farmers is also essential or fundamental to the Finnish programs in Mikkeli and in Helsinki. Organic farming and food products are an important and growing part of the food system in many countries, especially in Europe; therefore, it is essential to accelerate our interest and attention to developing new education programs.

References

Altieri, M.A. 1995. *Agroecology: The Science of Sustainable Agriculture*. Westview Press, Boulder.

Buck, D., Getz, C. and Guthman, J. 1997. From farm to table: the organic vegetable commodity chain of Northern California. *Sociologia Ruralis* 37: 1, 3–19.

Chaiklin, S., Hedegaard, M. and Jensen, U.J. (eds) 1999. *Activity Theory and Social Practice*. Aarhus University Press, Aarhus.

Dabbert, S., Häring, A.M., and Zanoli, R. 2004. *Organic Farming: Policies and Prospects*. Zed Books, London.

Edwards, C.A. Lal, R., Madden, P., Miller, R.H. and House, G. (eds) 1990. *Sustainable Agricultural Systems*. Soil and Water Conservation Society, Ankeny.

Engeström, Y. 1987. *Learning by Expanding. An Activity–Theoretical View on Developmental Research*. Orienta–Konsultit, Helsinki.

Francis, C., Lieblein, G., Gliessman, S., Breland, T.A., Creamer, N., Harwood, R., Salomonsson, L., Helenius, J., Rickerl, D., Salvador, R., Wiedenhoeft, M., Simmons, S., Allen, P., Altieri, M., Flora, C. and Poincelot, R. 2003. Agroecology: the ecology of food systems. *Journal of Sustainable Agriculture* 22(3): 99–118.

Francis, C., Salomonsson, L., Lieblein, G. and Helenius, J. 2004. Serving multiple needs with rural landscapes and agricultural systems. In: Rickerl, D. and Francis, C. (eds) *Agroecosystems Analysis*. American Society of Agronomy, Madison. pp. 147–165.

Francis, C.A. and Carter, H.C. 2001. Participatory education for sustainable agriculture: everyone a teacher, everyone a learner. *Journal of Sustainable Agriculture* 18 (1): 71–83.

Francis, C.A., Flora, C.A., and King, L.D. (eds) 1990. *Sustainable Agriculture in Temperate Zones*. John Wiley and Sons, New York.

Franzluebbers, A.J., and Francis, C.A. 1991. Farmer participation in research and extension: N fertilizer response in crop rotation. *Journal of Sustainable Agriculture* 2(2): 9–30.

Franzluebbers, A.J., Francis, C.A. and Walters, D.T. 1994. Nitrogen fertilizer response potential of corn and sorghum in continuous and rotated crop sequences. *Journal of Production Agriculture* 7: 193–194.

Gliessman, S.R. 1998. *Agroecology: Ecological Processes in Sustainable Agriculture*. Ann Arbor Press, Chelsea.

Goodman, D. 2000. Organic and conventional agriculture: materializing discourse and agro-ecological managerialism. *Agriculture and Human Values* 17: 215–219.

Hakkarainen, K., Palonen, T., Paavola, S. and Lehtinen, E. 2004. *Communities of Networked Expertise: Professional and Educational Perspectives*. Elsevier, Oxford.

Hatfield, J.L. and Karlen, D.L. (eds) 1994. *Sustainable Agriculture Systems*. Lewis Publishers, CRC Press, Boca Raton.

Hubert, B., Ison, R.L. and Röling. N. 2000. The problematique with respect to industrialized country agricultures. In: Cerf, M., Gibbon, D., Hubert, B., Ison, R., Jiggins, J., Paine, M., Proost, J. and Röling N. (eds) 2000. *Cow up a Tree. Knowing and Learning for Change in Agriculture: Case Studies from Industrialized Countries*. Institut National de la Recherche Agronomique, Paris. pp. 31–35.

Kirschenmann, F. 2000. The organic agriculture in North America: The organic movement at the crossroads. In: Allard, G. David, C. and Henning, J. (eds) *Organic Agriculture Faces its Development: The Future Issues*. Institut National de la Recherche Agronomique, Paris. pp. 63–74.

Lave, J. and Wenger, E. 1991. *Situated Learning: Legitimate Peripheral Participation*. Cambridge University Press, Cambridge.

Lieblein, G., Francis, C.A. Salomonsson, L. and Sriskandarajah, N. 1999. Ecological agriculture research: increasing competence through PhD courses. *Journal of Agricultural Education and Extension* 6(1): 31–46.

McLeod, M. 2004. Organic baby food 'worst for toxins.' Scotland on Sunday, 18 July 2004. Scotsman Publications, Edinburgh. <http://scotlandonsunday.scotsman.com/index.cfm?id=820492004>. Accessed 18 November 2004.

Michelsen, J. 2001a. Recent development and political acceptance of organic farming in Europe. *Sociologia Ruralis* 41(1): 3–21.

Michelsen, J. 2001b. Organic farming in a regulatory perspective: The Danish case. *Sociologia Ruralis* 41(1): 62–83.

Østergaard, E. 1998. One step back and two steps forward: A phenomenological study of farmers in conversion to ecological agriculture. PhD thesis, Department of Horticulture and Crop Sciences, Agricultural University of Norway, Ås.

Rzewnicki, P.E., Thompson, R., Lesoing, G.W., Elmore, R.W., Francis, C.A., Parkhurst, A.M. and Moomaw, R.S. 1988. On-farm experiment designs and implications for locating research sites. *American Journal of Alternative Agriculture* 3(4): 168–173.

Savory, A. 1999. *Holistic Management*. Island Press, Covelo.

Seppänen, L. 2002. Creating tools for farmers' learning: an application of developmental work research. *Agricultural Systems* 73(1): 129–145.

Seppänen, L. 2004. Learning challenges in organic vegetable farming: an activity theoretical study of on-farm practices. PhD thesis, Institute for Rural Research and Training , Helsinki University, Helsinki.

Seppänen, L. and Helenius, H. 2004. Do inspection practices in organic agriculture serve organic values? A case study from Finland. *Agriculture and Human Values* 21(1): 1–13.

Sfard, A. (1998). On two metaphors for learning and on the dangers of choosing just one. *Educational Researcher* 27(2): 4–13.

Vos, T. 2000. Visions of the middle landscape: organic farming and the politics of nature. *Agriculture and Human Values* 17: 245–256.

Woodward, L. and Vogtmann, H. 2004. IFOAM's organic principles. *Ecology and Farming* 36: 24–26.

Chapter 18

Organic agriculture: opportunities and challenges

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> The tradition in agriculture has been to maximize production and minimize the cost of food with little regard to impacts on the environment and the services it provides to society. As the world enters an era in which global food production is likely to double, it is critical that agricultural practices be modified to minimize environmental impacts even though many such practices are likely to increase the costs of production. (Tilman 1999)

Introduction

The organic movement may have gained a place in the spotlight of the mainstream media now, but it has not been like that for long. Since the 1950s, organic farmers operating at a grass roots level have devised, tested and shared production methods. They have codified a set of ideals into a pioneering best practice agricultural management system that addresses multiple community values. Niche markets have gradually been created, commonly based on trust and goodwill (formal certification did not begin until the 1960s and 1970s), and often using novel direct marketing strategies such as box schemes and community supported agriculture. After many years of consumers having to hunt around for their organic produce from several suppliers, perhaps directly from the farmer, the task is now a lot easier with specialist food shops and organic shelf space in supermarkets, in the industrialised world at least. Global links have been forged in all continents as organic agriculture has been seen to be an effective rural development option.

Although the movement is still regarded with some scepticism (e.g. Trewavas 2001, Kirchmann and Ryan 2004, Trewavas 2004), the concept of organic farming has strong marketing appeal, growth forecasts are almost all positive and it has been suggested that the ‘movement’ is now an ‘industry’ (Cornish and Stewart 2002). Organic agriculture is one of the fastest growing agribusiness sectors in the world, with double-digit annual growth in land under organic cultivation, value of organic produce and number of organic farmers. There are about 26 million hectares of organic farmland currently and the global market value of organic goods in 2003 was US$25 billion per year (Willer and Yussefi 2005, see also *Chapter 10*), about 2% of the US$1.3 trillion per year in global agricultural production (Wood *et al*. 2001). Furthermore, each year brings new peer-reviewed research showing the strengths and weaknesses of organic agriculture (see *Chapter 15*), a sign of growing interest by academics and funding bodies.

Despite the generally positive outlook, the organic movement faces several hurdles as it expands internationally. A recent review of organic farming listed several challenges facing organic agriculture (Halberg *et al*. 2005a) including:

- ecological justice;
- animal welfare;
- fair trade;
- supply chain development;
- productivity limitations; and
- regional adaptation and global harmonisation for standards.

Many of these can be seen through one lens, the need to remain dynamic. New issues and changed circumstances require on-going adaptation by the organic movement. To embrace these wider concerns, the organic movement needs to maintain flexibility in the regulations and the processes used to implement the regulations. As additional client countries and novel products apply for organic certification, new processes and production guidelines will be required in many cases (Woodward and Vogtmann 2004, Köpke 2005). After a period of expansion since the 1980s, a stage may have been reached where the organic movement is being confronted by limits in its ability to initiate change without itself changing (see *Chapter 9*). This tension has become explicit in the corporatisation of organic agriculture (Ikerd 1999, Guthman 2000, Sligh and Christman 2003, see also *Special topic 3* for further discussion).

The need for adaptability is increased by global marketing chains and electronic media that can now provide fast transfer of products and ideas. New commodities are continually being developed by producers and embraced by consumers. Even food scares can alter buying patterns very rapidly. In this dynamic marketing environment, organic agriculture is being moulded by socioeconomic factors well beyond its control (see *Chapter 17*).

But the process of reviewing and reflection within the organic movement is not new. The movement has continually transformed itself as it has grown and matured in Europe from the 1920s to the establishment of international groups, such as the International Federation of Organic Agriculture Movements (IFOAM) in the 1970s, and the export of organic farming beyond Europe has seen organic groups around the world create locally adapted networks and solutions to certification, production and supply problems (Reed 2003, see *Chapter 1*). Along with new territory, organic production has captured new industries, necessitating the development and integration of completely new standards for forestry, aquaculture and textiles (IFOAM 2005). Another challenge is the controversial role of contamination by genetically modified organisms (GMO). However, despite strong opposition to GMOs throughout the movement, senior members of the organic movement are beginning to look at the suitability of zero tolerance (Clay 2003).

Without robust and comprehensive social and environmental accounting, the broad question could be asked: Is modern conventional agriculture just an expensive indulgence for affluent countries? Although agricultural and food production in the modern world has successfully increased overall yields and overcome many biophysical limitations, it has also been a destructive force for the environment (Millennium Ecosystem Assessment 2005), excessively consuming key resources, such as soil and water mostly, underutilising 'waste' streams and thus polluting other resource bases (Box 18.1). It is in this context of current global land use that organic farming systems should be evaluated. Kasperczyk and Knickel (see *Chapter 12*) found that organic agriculture provided several environmental benefits including lower pesticide pollution, enhanced biodiversity and ecological services, improved soil health (i.e. organic matter, biological activity, nutrient cycles, erosion risk), and strong links between organic farmers and nature conservation activities (also see Lohr 2005). However, definite conclusions cannot be made for many places around the world because of the absence of data.

Box 18.1 Selection of findings highlighting the long-term impact of agriculture and related activities on natural resources (Wood *et al.* 2001 and Millennium Ecosystem Assessment 2005)

More land was converted to cropland since 1945 than in the 18th and 19th centuries combined, and now about one-quarter (24%) of Earth's terrestrial surface has been transformed to cultivated systems.

Moderate to severe soil degradation occurs on 52% of global agricultural lands.

Human activities now produce more biologically usable nitrogen than is produced by all natural processes combined.

More than one-half of all the manufactured nitrogen fertiliser (first produced in 1913) ever used on the planet has been applied since 1985.

The flow of nitrogen to the oceans has doubled since 1860.

Water withdrawals from rivers and lakes for irrigation, household and industrial use doubled in the last 40 years.

Humans now use between 40% and 50% of the freshwater running off land to which most of the population has access.

Total food production increased by about two-and-a-half times while the number of people in the world doubled from 3 billion to 6 billion between 1960 and 2000.

Despite the growth in per capita food production since the 1970s, an estimated 852 million people were undernourished in 2000–2002, up 37 million from 1997–1999.

The number of species on the planet is declining and the species distribution is becoming more homogenous.

Genetic diversity has declined globally, particularly among cultivated species.

Water and air pollution were more problematic in organic farming because of the reliance on manures, and Kasperczyk and Knickel also raised a common concern that economic pressures to maximise short-term production may compromise the beneficial aspects of organic agriculture.

Chapter 4 began with two important points that are worth restating here. First, organic growers are not homogeneous. Some farmers use 'substitution-based' approaches and are seeking premium prices for their goods. Others are 'subsistence' producers using organic methods by default. Between these groups are a range of philosophically committed organic growers who are more motivated by environmental and health issues. Second, Letourneau and van Bruggen (see *Chapter 4*) question the use of 'simplified' terms, such as organic and conventional, preferring instead to focus on specific management practices and agroecological mechanisms. By focusing on actual practices and processes within farming systems, it is expected that the observed effects of certain organic practices can be more clearly quantified and interpreted. The finding can also be generalised for other locations, crops or farming systems.

In this Chapter, key conclusions from earlier chapters have been compiled and summarised. Many themes were consistently reiterated in the various chapters, confirming the importance of those themes across a wide range of settings. Rather than speculating on the future of organic agriculture and its possible impact on world food security and the environment, this

Box 18.2 Benefits and opportunities for organic agriculture

Provision of ecological services, such as crop protection, yield stability and system resilience.

Reduced chemical residues in food and the environment.

Few strongly negative environmental impacts.

Economic performance is often equivalent to conventional farming.

High standards of animal welfare.

Reliable and credible standard-setting processes and certification schemes.

Dynamic review of policies and standards.

Strong consumer demand and brand recognition.

Indigenous knowledge is valued.

Potential for cooperative rural and regional development.

concluding chapter is more concerned with documenting and reviewing current knowledge, identifying strengths and weaknesses, and applying that information to the immediate challenges ahead. Opportunities for supporting the continuing development of the organic movement through cross fertilisation of technologies and conceptual approaches in the areas of supply chains and farming systems are discussed.

Opportunities and challenges

Organic farming has attracted considerable attention from those who see it as a panacea to those who see it as ideological nonsense. A more humble responsibility for the organic movement may be to serve as role model for a farming system in which values other than financial are cultivated (see *Chapters 8* and *14*). Organic farming asks how we ought to relate to each other and our natural environment (see *Special topic 3*). The values of the organic movement are not esoteric, but are based on observation and common sense: treat livestock well, use resources sparingly, use the least harmful method, nature is inherently valuable and so on. Food security depends upon personal relationships of integrity and trust among farmers, farm workers, suppliers, consumers and others up and down the agricultural supply chain (see *Special topic 3*), and integrity and trust have been fundamental to organic agriculture's success.

There are many other role models across the spectrum of agricultural systems, such as conservation tillage, permaculture and traditional farming systems, but organic farming has emerged as one of the best known alternative farming systems developed in response to the shortcomings of mainstream agriculture. Many of the key benefits and opportunities for organic agriculture (Box 18.2) are suitable areas for the organic movement to show leadership and innovation, including assurance and auditing procedures, rural and regional development and low cost agricultural systems relying on biological and ecological processes.

A range of challenges that were highlighted in other chapters are listed in Box 18.3. Some of these challenges are in conflict with each other (e.g. global harmonisation versus local adaptation) and some challenges are also opportunities (e.g. dynamic review of policies and stand-

Box 18.3 Challenges for organic agriculture

Maintaining sustainability in the global economy: balancing organic principles with commercial imperatives.

Maintaining flexible organic standards and certification processes to address issues such as:
- nature conservation and regeneration;
- equitable, affordable and flexible access to certification services;
- responsible labour relations and land tenure arrangements;
- animal welfare;
- new inputs such as 'natural' biocides, soil amendments and GMOs; and
- incomplete or unscientific basis for including/excluding materials from organic standards.

Pursuing international harmonisation of standards and certification.

Developing locally applicable agronomic solutions to production constraints, such as weeds, animal health and soil fertility.

Expanding research activities in many disciplines (particularly beyond Europe and North America) and foster the integration of knowledge.

Preserving food quality while trying to increase productivity.

Educating and training at all levels to build capacity, infrastructure and networks.

Inadequacies in regulatory and marketing structures (e.g. labelling).

Excessive consumer prices and inconsistent quality and availability.

Establishing and maintaining credibility and professionalism.

ards). Specific local agronomic requirements can also create pressure to modify standards. For example, phosphorus (P) fertilisers allowed under the certification standards are unable to supply adequate P in the inherently deficient soils in parts of southern Australia. Consequently, the restriction on citrate-soluble superphosphate has been questioned (Penfold 2000).

The question of whether organic food is better for human health than conventional food is central in the minds of organic consumers (see *Chapter 11*). Yet the research indicates that no definitive nutritional differences have been found (see *Chapter 13*). Reviews in several countries all concluded that there is no evidence for any direct health benefits associated with the consumption of organic foods. These reports also concluded that there were no health risks associated with organic food. Differences were reported for a range of nutritional characteristics, but there is no consistency across the literature.

Despite the lack of nutritional differences in the comparative review, examination of large data sets showed that organically grown foods consistently had about one-third of the pesticide residues in conventionally grown foods (Baker *et al.* 2002). There are also numerous examples in the broader research literature that showed links between food production methods and food quality, and that these differences are large enough to influence consumer health (see *Chapter 13*). By gaining an understanding of the relationships between production methods and food quality, improvements can be made in the quality of produce from a system, whether it is organic or conventional. However, there are limitations in the experimental approach of some of the studies, such as confounded designs, inadequate time frames and not targeting aspects where differences are most likely. Brandt and Mølgaard note the scientific evidence shows that only organic methods have demonstrated the ability to improve both yield and nutritional quality simultaneously, and that organic principles effectively protected against 'mad cow disease' (bovine spongiform encephalitis).

The yields in organic agriculture may be equivalent to or better than conventional agriculture, although often they are not, simply because of inadequate plant available nutrients, weed infestation, non-cash phases in the crop rotations or inexperienced management (see *Chapter 1*). Yield performance is very location and management specific and many underlying drivers (e.g. soil carbon, weed seed banks) of yield have long responses times (Martini *et al*. 2004, see *Chapter 15*). Some researchers have also highlighted the value of alternative agroecological criteria such as resilience and stability (Trenbath 1999, Lotter *et al*. 2003). Although organic agriculture causes less pesticide contamination in food, people and the environment, it is premature to claim that organic agriculture is completely environmentally sustainable (see *Chapter 12*). In particular, some soil nutrients have negative budgets in certain organic cropping systems, causing a depletion of soil reserves of that nutrient (see *Chapter 1*).

Looking to the future

Organic agriculture will always be operating in a broader context of powerful market forces controlling the flow of inputs and outputs including intellectual property. Social expectations about agricultural production systems and consumer preferences also interact closely with the market place creating an uncertain future for organic growers and traders. Lockie *et al.* (see *Chapter 11*) are cautious about making predictions about the size of the organic market into the future. Predictions are difficult because of changing global demographics and dietary tastes, as well as the knowledge that past successful marketing strategies may not remain effective.

The same caveat should apply to predictions about global organic expansion and the consequent inability to feed the world (Avery 1997). The challenge of feeding the world applies to any modern farming system, as the Millennium Ecosystem Assessment Synthesis (2005) report reminds us: global food production is adequate, yet poverty and environmental destruction persist. Whatever agricultural system, or hybrid of systems, is used to provide food and fibre for the international community, it will presumably be supported by democratic governments, the business community and by farmers and consumers, and problems will be solved progressively. A range of feedback mechanisms is likely to evolve to maintain equilibrium between production and sustainability:

- 'mainstreaming' the 'alternative', possible mass market opportunities;
- preventing excesses through regulation (e.g. onerous compliance for registration of inputs); and
- supporting transition through enabling policies, e.g. subsidies, harmonisation, brokering and collaboration, research funding (Thirsk 2000, Pretty *et al.* 2003, Stoneham *et al.* 2003).

Organic farming systems have not been optimised over many decades by large inputs of time and money for research, industry development and extension services in the same way that conventional farming systems have. Therefore, the ability of the organic movement to provide a broad solution to global food and fibre production problems is limited in current circumstances. Although organic farming systems have some well recognised benefits, widespread adoption of organic agriculture as the sole method of farming is unlikely in the short-term to medium-term, even in the most progressive countries in Europe. Modelling of large-scale conversion to organic agriculture at realistic rates (10–20%) indicates that such conversion would be unlikely to cause adjustment problems to the agricultural sector, for example, as a result of significantly lower yields (Halberg *et al*. 2005b, see *Chapter 10*).

The report of the Millennium Ecosystem Assessment (2005) lists several general strategies for promoting more sustainable land use that are very applicable to organic agriculture. These strategies include creating appropriate governance and marketing structures, overcoming social and behavioural constraints, encouraging investment in the development and diffusion of suitable technologies and fostering a robust knowledge and skills base. Several more specific policy options were also recommended:

- removal of production subsidies that have adverse economic, social and environmental effects;
- investment in, and diffusion of, agricultural science and technology that can sustain the necessary increase of food supply without harmful tradeoffs involving excessive use of water, nutrients or pesticides;
- use of response polices that recognise the role of women in the production and use of food and that are designed to empower women and ensure access to and control of resources necessary for food security; and
- application of a mix of regulatory and incentive-based and market-based mechanisms to reduce overuse of nutrients (Millennium Ecosystem Assessment 2005).

The importance of recognising the role of women is reinforced by Lockie *et al*. (see *Chapter 11*) who state that gender, not education or income, is the most important demographic factor influencing patterns of organic consumption, because women report purchasing organic foods more than men.

There is a diverse range of emerging and existing technologies and conceptual approaches that are compatible with organic agriculture, and where organic agriculture has existing strengths, such as adult education and soil microbiology (Figure 18.1). These technologies can provide the organic movement with opportunities to improve productivity, overcome marketing constraints, reduce harmful environmental and social impacts and maintain a progressive, constructive stance in relation to research, development and education. The following discussion about the ongoing role of the organic movement in agriculture is based on the broad, non-exclusive topics, supply chains and farming systems, identified in Figure 18.1. These topics each have several themes listed as examples; however, these lists are not intended to be exhaustive.

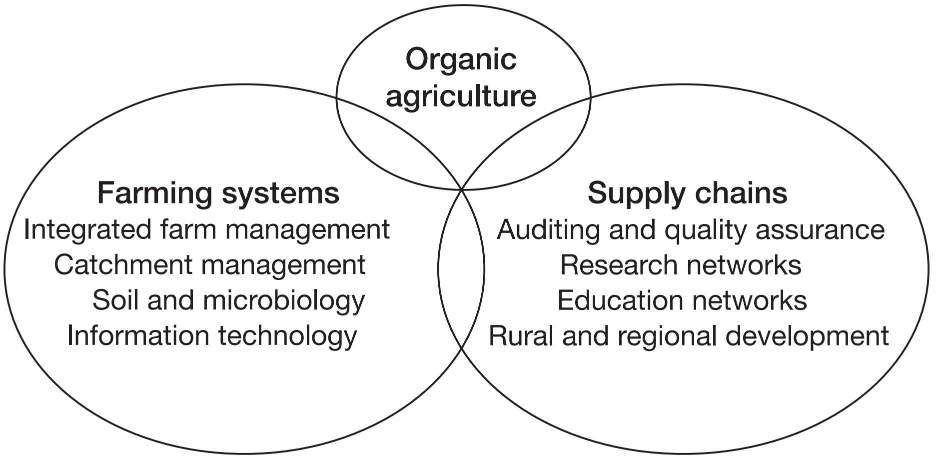

Figure 18.1 Technologies and conceptual approaches relevant to organic agriculture.

Supply chain technology

There are numerous parts of an agricultural supply chain, with many stakeholders. A consequence for organic agriculture is that there are many areas that need to be established, modified and strengthened. Major areas of interest are:

(a) the creation and expansion of knowledge networks for research and education;
(b) continuing revision of the organic standards and certification processes; and
(c) a clearer role of organic farming in rural and regional development.

Knowledge networks – research

To enable organic agriculture to grow and mature several supporting mechanisms are needed. Such mechanisms include on-farm and collaborative research, teaching at a wide range of competencies from farmer field days to doctoral studies (see *Chapters 15*, *16* and *17*), a comprehensive and reliable knowledge base, widely accessible information flow lines and a diverse pool of skilled people. Much of this process is under way, but considerable effort is still required.

Research is vital for sectoral development as it allows new knowledge to be developed, such as increasing yield and productivity, quantifying environmental and social impacts, minimising adverse effects and maximising benefits (see *Chapter 15*). Research and development in organic farming is normally constrained by scarce funding from governments and large commercial stakeholders, and smaller commercial players are generally unable to allocate funds for research and development (Wynen 2003). There are no fundamental essential barriers to establishing cross-disciplinary research collaborations, but various practical and structural barriers exist including access to funding, cost of larger long-term trials and project coordination difficulties (see *Chapter 15*).

Despite criticisms about a lack of objectivity in organic research, almost all research activities are inherently value-laden, with choices routinely being made about subject matter, funding sources, treatments to apply and methodologies to follow (see *Chapter 15*). No single research strategy is adequate to address the needs of the global organic agriculture movement. Instead, there are several issues to consider. A balance needs to be achieved between reductionist and holistic approaches (combining disciplinary and systems thinking), between short-term and long-term trials and between multidisciplinary and single discipline projects. The process of data collection, synthesis and interpretation should take place at all levels from the 'plots and pots' of experimental trials to whole farms, and from catchments and bioregions to local and global markets. Action, participatory and on-farm research approaches provide a range of options for encouraging cooperation between project stakeholders, although their effective use depends on the interests of the stakeholders and facilitation skills of the project leaders (see *Chapter 15*).

Relatively new organisations such as the International Society of Organic Agriculture Research, Colloquium of Organic Researchers in the United Kingdom (UK) and The Organic Center, as well as the Scientific Committee for Organic Agriculture Research in the USA demonstrate that the organic movement is moving to another level of sophistication in pursuing research. Together with the growing number of private and government research centres being established (see *Chapter 15*) and universities offering study programs in organic farming (see *Knowledge networks – education*), there is an opportunity to produce more research, produce better quality research and to reduce research overlap by increasing collaboration.

It is common (and logical) for researchers to highlight the need for further research in their discipline, and that is true of all chapters in this book. Some specific areas where research has been absent or less intensive include:

- environmental impacts (see *Chapter 12*);

- social dynamics (see *Chapters 9*, *11*, *14*, *16* and *17*);
- animal husbandry (see *Chapters 7*, *8* and *9*);
- determining goals for breeding and selection and maintaining genetic diversity, including livestock rare breeds and heirloom crop varieties (see *Chapters 4*, *5* and *6*); and
- economic management, specifically market access, price stability and cash flow (see *Chapter 10*).

Knowledge networks – education

Much of the education and training in organic agriculture has taken place in apprentice-type situations with farmers as teachers and young people as learners in a practical, hands-on learning environment. This has evolved into the global tradition of strong farmer groups in the organic movement (see *Chapter 16*). Some of this experience is being captured through farm visits and other teaching methods, and linked with educational theory to develop courses in organic agriculture in universities. Like research into organic agricultural systems, there is usually a lack of institutional support in most countries. The only consistent exceptions are courses offered by organic grower groups. International tertiary education links have been established within European countries and between Europe and other regions such as North America and Australia. Many universities now offer individual subjects, majors and full courses in organic agriculture, providing a valuable pool of agronomists, veterinarians, extension officers and other specialists with specific training in organic principles and practices (see *Chapter 16*).

Organic farms are inevitably complex places, with greater biological and enterprise diversity than conventional farms (see *Chapters 12* and *17*). There are many competing factors to manage and decision making is challenging. In addition, these is less chance of contacting a commercial or government agronomist and seeking advice, though this is changing as the upstream end of the supply chain grows with 'biofertiliser' products proliferating at agricultural field days and in industry magazines. Sound management skills and independence are therefore vital. These preconditions for successful organic farming – complexity and independence – are important because they influence how organic education can be taught (see *Chapter 17*). In developing a curriculum, a course should 'help prepare students to deal with the complexity and uncertainty they will face in working for sustainable agriculture and food systems for the future' (see *Chapter 16*). In several tertiary courses on organic agriculture there is an expectation that organic agriculture students will be able to cope with student-centred learning, perhaps on a problem-based learning or case study project (Lieblein *et al.* 2005). Student-centred learning is preferred because it increases the amount of information processing, as opposed to simple memorising, producing deeper learning (see *Chapters 16 and 17*). There is also an emphasis on experiential learning, preferably involving considerable interaction with organic farmers on their farms. Although not exclusively relevant to organic agriculture, integrated teaching approaches have good conceptual alignment with integrated (organic) farming approaches as both foster skills in managing complexity and independent critical thinking (see *Chapter 17*). The teaching approach suggested by Sriskandarajah *et al.* (see *Chapter 16*) and used in many agricultural courses around the world has limitations, including the costs involved with running field trips for students, the facilitation skills required to deliver experiential-based curricula effectively and the inflexible administrative structures of tertiary institutions.

The conceptual models presented in the chapters on social responsibility, tertiary education and farmer education show uncanny harmony (Table 18.1). Despite considerable disciplinary overlap, this convergence of models was not as a result of similar theoretical sources (the relevant citations are different in each chapter). Instead, the models highlight the simple

Table 18.1 Conceptual models presented in the chapters on social responsibility, tertiary education and farmer education

Conceptual model	Source
Learning = regulation × cooperation	Pyburn *et al.* (see *Chapter 14*)
Knowledge = information × processing	Sriskandarajah *et al.* (see *Chapter 16*)
Knowledge creation = knowledge acquisition × participation	Seppänen and Francis (see *Chapter 17*)

dichotomy of 'thinking and doing' (matter and energy) as the common factors required to produce an action or outcome, in this case learning. As the manager of a complex agroecosystem, a capable organic farmer or student will need to be able to think and do simultaneously, compile and integrate information from different sources, make and implement decisions, review past performance and revise future strategies. A good conventional farmer would do the same, but he or she would have greater recourse to finding people to do the thinking for them – the commercial agronomists, long established marketplaces and supply lines, a shared history of production methods within a district, the industry magazines and so on. However, organic growers have traditionally not had those options, and acquiring generic, ready-made knowledge is likely to be insufficient (see *Chapter 17*). In addition to the lack of information and infrastructure, organic farmers are obliged to achieve production goals with less reliance on externally inputs and to pursue non-economic values such as maintaining and creating social and ecological capital. These demands create a high level of biological diversity and managerial complexity that, again, conventional growers may choose not to pursue, instead focusing simply on maximising yields and profitability.

Auditing and quality assurance systems

The organic standards setting and certification systems were developed to ensure that organic produce is genuine, potentially the most important strategy in the marketing of organic goods (see *Chapter 11*). Three main regulatory challenges facing organic agriculture are:

(a) international harmonisation and the tensions between regulatory agencies;
(b) ensuring stringency in assurance systems for global consumers while also allowing for locally appropriate adaptations; and
(c) and ensuring equitable access to organic certification systems, particularly in developing countries (see *Chapter 9* and *Special topic 3*).

An underlying theme in such challenges is one of balancing competing needs.

The organic movement now has many more stakeholders than in the mid-1980s, and these voices all deserve to be heard in such an overtly democratic movement (e.g. IFOAM 2005). Although it will take considerable time and cooperation, international harmonisation is a necessary and possibly inevitable process (see *Chapters 9* and *10*). The International Task Force on Harmonisation brings regulatory agencies together to compare each others' systems and evaluate various other programs and models (see *Chapter 9*), but countries without their own standards will be at a disadvantage (see *Chapter 10*) and separate national disputes will continue to hinder progress (Lotter 2003, Alexandra and May 2004).

In Chapter 14, Pyburn *et al.* advocate a mixture mechanism to stimulate and provide incentives for social responsibility throughout the supply chain. To achieve more than superficial change in social responsibility, a learning approach can provide a hands on, direct experience for people and groups affected by social issues in agriculture. Standard setting needs to be based on support by several stakeholders in the organic food chain, including collaboration between organic certifiers and other social certifiers, such as FairTrade Labelling Organizations International and the International Labor Organization. Internal Control Systems have been used for group certification in developing countries (see *Chapters 9* and *14*). Various stakeholders including farmers and certification agency representatives meet for discussions, out of which comes a new understanding for farmers (e.g. more technical knowledge about organic farming, expanded personal networks) and agency staff (e.g. more knowledge about local constraints for organic production), and ultimately refined standards and certification methods are produced. Ideally, the standards are temporary and always subject to revision, and are the outcome of a cooperative learning process rather than an instrumental process dominated by a few powerful interests (see *Chapter 14*).

Strategies to maintain and strengthen the effectiveness of organic certification have been identified (Consumers Union 2003, see also *Chapters 7*, *9*, *10* and *14*):

- internal control systems as a tool for smallholder group certification;
- participatory guarantee systems in formalised regulatory systems;
- complementary regulatory structures to provide assurance across sectors and regions;
- transparent auditing and verification systems; and
- approval of allowable inputs based on peer-reviewed science.

Rural and regional development potential

More people depend on agriculture in developing countries than in the industrialised countries of Europe, North America and parts of Asia-Pacific. Subsistence is often the first priority, after which goods for the market can be bartered or sold for cash. In this scenario, organic agriculture, or parts of it at least, may be a useful development tool. Just as integrated teaching methods suit organic farming courses, the emphasis on integration and multidisciplinarity in organic farming readily complements participatory approaches to development, and indigenous intellectual and material resources are often compatible with organic farming (see *Special topic 5*).

There are many examples of the beneficial role of organic agriculture in sustainable development in poorer rural areas (e.g. Parrott *et al*. 2005, Tafuna'i 2005, see also *Chapters 7*, *9*, *14* and *Special topic 5*), although its effectiveness has been poor in many places partly as a result of a lack of local demand for certified organic products and limited export potential due to compliance problems (e.g. cost and disease restrictions) (see *Chapters 7* and *14*). Agricultural development projects should start from existing local practices, yields and knowledge and not from the promises of a new technology. Extension and support should be a mixture of technical, social and cultural approaches suited to the learning styles of the target group. Where possible, activities should expand beyond an initial disciplinary subject approach using a top-down extension method into an integrated approach with a participatory development process. These guidelines would be relevant for extension and research activities with farmers in any country and are not unique to development settings (see *Special topic 5*).

Farming systems technology

To develop a successful farming system requires a combination of personal skills, suitable land and a market for the produce. In particular, successful on-farm production requires careful consideration of local conditions. Although the organic standards and the collective knowledge of organic farmers can be used for guidance, some experimentation will be required to manage each unique combination of weeds, pests and soil imbalances. For example, internal parasites in livestock pose a major problem for organic and low-input sheep graziers around the world and conventional graziers are facing resistance to chemical drenches (Welsman 2001, Keatinge *et al*. 2002, Githiori *et al*. 2003). The potential for collaborative research into non-chemical means of managing livestock parasites could involve grazing strategies, phytomedicines, breeding and novel veterinary treatments (e.g. homeopathy) (see *Chapters 6*, *7* and *Special topic 2*).

In some highly weathered soils and semi-arid environments, essential soil nutrients, such as P, are likely to be limiting and the options permitted under current organic standards may be inadequate and considered unsustainable (Kirchmann and Ryan 2004, see also *Chapter 2*). Furthermore, in some countries, the distance between farms and the primary sources of key inputs is large and the range of inputs becomes severely restricted (Buresh *et al*. 1997).

Given that soil fertility is central to organic production, this aspect of negative nutrient budgets should not be dismissed too easily because the question of P has been raised in a variety of settings in Germany (Lampkin 1990) and the UK (Gosling and Shepherd 2005) and, away from temperate Europe, in Sub-Saharan Africa (Pender and Mertz 2005) and Australia (Penfold 2000). Based on current data, for some places in the world, rock phosphate will not be able to provide plant-available P to the soil quickly enough (see *Chapter 2*). Biological, chemical and physical methods of increasing the effectiveness of rock phosphate are being investigated, with a focus on the following factors:

- mineral properties: reactivity, particle size, surface area;
- soil factors: pH, titratable acidity, P and calcium (Ca) availability and retention, sand content, biological activity, organic matter content, moisture, temperature; and
- plant factors: P and Ca demand, root structure, rhizosphere pH (see *Chapter 2*).

However the effects are often neither significant nor important agronomically (Ryan and Ash 1999, see also *Chapter 2*). Like collaborative research into sheep parasites, there are many stakeholders interested in improving soil P availability.

Despite some serious but localised problems, organic farms are either already in practice or are possible to establish in many agricultural settings (see *Chapter 4*). The constraints that exist are often similar to those faced by conventional farmers (soil fertility, plant and animal health) and there is considerable common ground in rectifying issues such as improved P solubilisation and non-chemical parasite control in livestock. Some of the agricultural technologies that organic growers can and do use are now discussed.

Integrated farm management

Many different schemes have been established to devise and promote more efficient, less environmentally damaging methods of agricultural production. A myriad of these integrated management schemes can normally be identified by their acronym, for example Integrated Pest Management (IPM), Low External Input Sustainable Agriculture (LEISA) and Environmental Management Systems (EMS). The common element among these concepts is that of achieving production goals by integrating a diverse range of strategies in a planned but flexible way. These approaches have clear links with organic principles of diversity and rely on ecological processes to aid production. In regard to managing crop protection, Letourneau and van Bruggen (see *Chapter 4*) have distilled three important principles related to managing invasive species ecologically: prevention of colonisation or establishment, population regulation through biological processes and curative interventions. Weed and animal health management would be expected to operate on similar principles (see *Chapters 1, 7* and *Special topic 1*).

As discussed, there is potential to learn from developing countries, such as those starting to adopt organic farming methods. Indigenous agricultural knowledge systems offer many innovative ideas for low-input farming that could be adapted for use on organic farms in other countries (Nyeko *et al*. 2002, Vogt *et al*. 2002, Cools *et al*. 2003). The use of the plant neem (*Azadirachta indica*) is an especially well-recognised example of indigenous knowledge.

Organic plant and animal breeding uses classical methods of crossing and selection based on desirable traits (see *Chapters 4*, *5* and *6*). The traits required for an organic ecosystem are often different to traits for conventional farm ecosystems, thus requiring organic-specific variety trials to determine performance. In plant breeding, various traits such as early vigour and leaf orientation are used because of their contribution to ecological crop protection (see *Chapters 3 and 5*). Research and commercial opportunities exist for producing new lines of organic seed varieties. Several large European seed companies have begun marketing organic seed; however, several small organic seed merchants have also become established where local demand for organic seed has made it viable (Neeson and Howell 2003). One step down the supply chain is seedling production, mostly for use on organic herb and vegetable farms. This sector of the conventional nursery industry is highly regulated and mechanised and therefore very cost efficient. Modifying such systems to suit organic methods, or developing alternative methods, is a priority because of the planned ending of derogation rules that allow organic growers to use conventional inputs when suitable organic supplies do not exist (Pearce *et al.* 2000, Greer 2002, White 2005). The recent growth in the organic seed and seedling sector indicates the flow-on demand along the supply chain from farmers seeking local cultivars suited to organic conditions (see *Chapter 5*).

Livestock, especially cattle, have a long and essential part in the history of organic farming (Lampkin 1990). Their ability to perform cost-effective multiple functions is world renowned for draught, weeding, milk, hides, meat and several types of organic fertiliser, such as manure and blood-and-bone. Unlike crops, animals are not simply components of a farming system. Animals are also sentient creatures and therefore can be expected to have certain moral rights (see *Chapter 7*). In biodynamic agriculture, the cow has a special place as provider of horns and other organs in the manufacture of various compost-based and manure-based soil conditioners (see *Special topic 2*). Although organic principles recognise the importance of having a natural life, natural living does not automatically imply good welfare. Key health and nutrition requirements also need to be met. Nevertheless, organic animals have similar health and welfare experiences compared to conventionally managed animals (see *Chapter 8*).

The role of catchments (or watersheds) in providing ecological services to agriculture has often been underrecognised, although there is growing interest among mainstream researchers in evaluating methods of integrating farmland, natural vegetation, water bodies and other landscape features (Stirzaker *et al.* 2000, van de Ven *et al.* 2003). In addition to work on the ecological services provided by diverse landscapes (see *Chapter 4*), research on systems design has investigated perennial systems, farm layout, crop rotations, water management and so on (Doing 1997, Kuiper 1997, Vereijken *et al.* 1997, see also *Chapter 1*). In many cases, the issue of adoption is a concern, especially if compliance is complex or costly, or where the benefits are difficult to discern (Ridley 2005).

Soil biology and microbial ecology

The importance of biology in maintaining soil health and fertility has always been appreciated by the organic movement. It is one of the most fundamental aspects of how soil is conceptualised in organic agriculture (IFOAM 2002). For many years this was a key feature distinguishing organic farming from conventional farming, where the latter system was almost entirely focused on chemical and physical properties of soil (see *Chapter 2*). However, with growing interest in the biological aspects of soil fertility, there are technologies available that can help measure biological activities and composition and these tools are very useful for evaluating the performance of different farming systems or different treatments within a farming system. Studies in molecular microbiology and soil microbial diversity have the potential to improve our understanding of complex nutrient cycles (see *Chapter 2*). Analytical techniques using, for example, phospholipid fatty acids and substrate-induced respiration provide the ability to study microbial community structures and population dynamics, factors that can be related to soil properties such as nutrient availability, structure and pathogenicity (Carpenter-Boggs *et al.* 2000b, Svensson and Pell 2001, Harris 2003, Steenwerth *et al.* 2003).

Although microbes have been shown to improve various soil quality parameters in different soil types and environments, yield improvements are not always observed and generally speaking the addition of significant volumes of organic matter is essential to increase the size or activity of the soil biological community (Edmeades 2003, see also Chapter 2). Soil organic matter content is especially difficult to increase in some environments; for example dryland, semi-arid environments with high temperatures and low precipitation, threatening the sustainability of organic farms in such areas (see *Chapter 2*). Increasing soil organic matter in organic agriculture is restricted by:

(a) slower accumulation of organic matter inputs compared with conventional farms as a result of lower crop yields and less intensive animal production systems;
(b) organic leys decomposing more quickly because of lower carbon to nitrogen ratios; and
(c) tillage required for weed control (Gosling and Shepherd 2005).

The application of microbial ecology (e.g. soil food webs) to agricultural production systems has provided a useful framework for understanding a range of soil processes including nutrient mineralisation and pathogen control (Ingham *et al*. 1985, Drinkwater *et al*. 1995, Wardle *et al*. 1999, Manici *et al*. 2004). Several specific strategies for increasing microbial activity have been developed such as effective microorganisms, compost teas, biodynamic preparations and so on (Sena *et al*. 2002, Chen *et al*. 2003, Compost Tea Task Force 2004, see also *Special topic 2*); however, many have not been rigorously evaluated and the mechanisms of action remain unclear (see *Chapter 2*).

In addition to maintaining soil health, microbes are also important in converting manures, crop residues and other organic materials into composts, humus and plant available nutrients (Welbaum *et al*. 2004, see also *Chapter 2* and *Special topic 2*), providing biological control of certain pests and diseases (Trejo-Estrada *et al*. 1998, Brimner and Boland 2003) and decomposing crop residues in the paddock (Vazquez *et al*. 2003).

A general objective in biodynamic soil management is to produce a compensating, stabilising influence on growth in which extremes are avoided (Goldstein and Barber 2005, see also *Special topic 2*). Biodynamic farmers utilise microbial activity in a unique way through the use of manure-based preparations (Raupp 1999) and positive agronomic and economic outcomes have been reported many times for biodynamic systems in different circumstances (e.g. Reganold 1995, Mäder *et al*. 2002). Attempts to measure the effect of biodynamic preparations are often limited by factors such as insufficient time under biodynamic management and confounding with whole-system effects (Carpenter-Boggs *et al*. 2000a, see also *Special topic 2*).

Conservation tillage

Tillage has been a necessary part of agriculture for centuries and it remains a key tool in organic farming. Important functions performed by tillage are seedbed preparation, incorporation of soil amendments, increasing soil mineralisation, crop protection and, most commonly, weed control. However, over-reliance on tillage, rather than tillage itself, is problematic in several situations, such as erosive, compacted, dry or wet soils and on sloping ground. The consistent lack of negative effects by organic farming on soil structure and microbial activity suggest that organic management practices are contributing to a resilience in the soil (see *Special topic 4*).

Many of the positive soil and water conservation benefits from conservation tillage practices can be lost in organic farming systems as a result of the reliance on multiple inversion tillage operations for seedbed preparation, incorporation of cover crops and weed management that can degrade soil quality (see *Chapter 2*). High-residue reduced-till systems using commonly accepted grass–legume mixtures, permanent soil cover and very limited strategic tillage offer the potential to synchronise nutrient supply with crop demand and multiple non-nutrient effects, including weed suppression, soil aggregation, resistance to erosion, biological pest management, and water infiltration and availability (see *Special topic 1*).

Successful examples of organic and non-chemical no-tillage systems have been demonstrated. These have all been short-term systems located in areas with long warm seasons (see *Special topic 1*). On the contrary, temperate organic no-till systems and permanent organic no-till systems have specific challenges due to slower cover crop growth and breakdown, different weed types and limited control options (see *Special topics 1* and *4*). Difficulties faced in organic no-till systems include producing adequate cover crop growth to perform agroecological functions properly, lack of reliable implements for effectively terminating the cover crop to prevent regrowth, and managing cover crop residues prior to sowing or planting the cash crop to maximise germination and establishment of the following cash crop (see *Special topic 1*). While effective organic no-till systems are still in the developmental phase, other options for reducing tillage are available, such as monitoring the soil organic matter budget to inform choices about tillage operations (see *Special topic 4*), strip cropping with semi-permanent beds (see *Special topic 1*) and using a ley phase in the crop rotation (see *Special topic 4*).

Information technology

Advances in information technology have created tools for recording, managing, analysing and presenting data. Various computer models and decision support systems have been used in an organic setting to explore nutrient and weed management (see *Chapter 3*), crop protection (see *Chapter 4*) and conversion impact (Halberg *et al*. 2005b, see also *Chapter 10*). Aspects of precision agriculture such as remote sensing and geographical information systems can also be adopted by organic farmers for a range of uses, such as land use planning (Gijsbers *et al*. 2001), improving tillage accuracy in weed management (Tillett *et al*. 2002, Rösch 2006) and improving fertiliser use efficiency in soil management (Goulding 2000, see also *Chapter 17*).

The development and use of indicators to evaluate farm performance are also relevant to organic agriculture. By monitoring farm performance, we can compare various management options and evaluate indicators over time on a farm, or make comparisons across farming systems (see *Chapter 12*). Numerous reports on the use of environmental and economic indicators are available (Roberts and Swinton 1996, Hendriks *et al*. 1997, OECD 1999, Helander and Delin 2004) and almost as many regarding the suitability and selection of indicators (Youngs *et al*. 1991, Eckert *et al*. 2000, Pannell and Glenn 2000, Bouma 2002). Indicators are used to measure a multitude of characteristics for different reasons and the users should be matched with the appropriate indicator tools. For example, farmers are more likely to use indicators that are easy to implement and interpret, are affordable, have a clear relationship to farm management practices and provide guidance for improving land management (King *et al*. 2000, Sulser *et al*. 2001, Ridley *et al*. 2003).

Summary

The organic movement has a range of strengths in various areas including agriculture and food production, international relations, direct marketing and process auditing. Fuelled by strong global consumer demand for ethically produced goods, the organic movement is expected to continue growing and diversifying. However, important issues need to be addressed such as balancing organic principles with commercial pressures and maintaining flexible (locally appropriate) standards and certification while also pursuing international harmonisation.

Most of the successes of the organic movement over the past decades have been achieved through the vision and enterprise of individuals and local farming groups operating without the support of government or agribusiness. As government and agribusiness groups are increasingly collaborating with the organic movement, it is anticipated that the beneficial impacts of organic farming systems will be further improved, and that the negative impacts will be minimised or avoided.

Organic agriculture will continue to challenge its critics as increasing numbers of successful enterprises are established in various countries. Organic proponents will also be challenged as new ethical questions emerge and the task of reviewing and improving organic farming methods is tackled. The organic movement has grown beyond its roots of farmers, growers groups and loyal consumers to a global niche industry. With new stakeholders and different stakes, the organic movement now has the opportunity to form more beneficial relationships and interact more directly with all key players in agricultural development.

References

Alexandra, J. and May, R. 2004. *Australian Organic Agriculture – Prospects for Growth?* Rural Industries Research and Development Corporation, Barton.

Avery, D. 1997. Saving the planet with pesticides, biotechnology and European farm reform. *Brighton Crop Protection Conference - Weeds* 1: 3–18.

Baker, B.P., Benbrook, C.M., Groth, E. and Lutz Benbrook, K. 2002. Pesticide residues in conventional, integrated pest management (IPM)-grown and organic foods: insights from three US data sets. *Food Additives and Contaminants* 19(5): 427–446.

Bouma, J. 2002. Land quality indicators of sustainable land management across scales. *Agriculture, Ecosystems and Environment* 88(2): 129–136.

Brimner, T.A. and Boland, G.J. 2003. A review of the non-target effects of fungi used to biologically control plant diseases. *Agriculture, Ecosystems and Environment* 100(1): 3–16.

Buresh, R.J., Smithson, P.C. and Hellums, D.T. 1997. Building soil phosphorus capital in Africa. In: Buresh, R.J., Sanchez, P.A. and Calhoun, F. (eds) *Replenishing Soil Fertility in Africa*. Soil Science Society of America/American Society of Agronomy, Madison. pp. 111–149.

Carpenter-Boggs, L., Kennedy, A.C. and Reganold, J.P. 2000a. Organic and biodynamic management: effects on soil biology. *Soil Science Society of America Journal* 64(5): 1651–1659.

Carpenter-Boggs, L., Reganold, J.P. and Kennedy, A.C. 2000b. Effects of biodynamic preparations on compost development. *Biological Agriculture and Horticulture* 17(4): 313–328.

Chen, S.-K., Edwards, C.A. and Subler, S. 2003. The influence of two agricultural biostimulants on nitrogen transformations, microbial activity, and plant growth in soil microcosms. *Soil Biology and Biochemistry*. 35(1): 9–19.

Clay, L. 2003. Facing up to GMO and realities. *Acres Australia* 11(1): 13.

Compost Tea Task Force 2004. *Compost Tea Task Force Report*. National Organic Standards Board, Washington DC.

Consumers Union. 2003. *Consumers Union Guide to Environmental Labels*. Consumers Union, Yonkers. <http://www.eco-labels.org>. Accessed 20/9/03.

Cools, N., De Pauw, E. and Deckers, J. 2003. Towards an integration of conventional land evaluation methods and farmers' soil suitability assessment: a case study in northwestern Syria. *Agriculture, Ecosystems and Environment* 95(1): 327–342.

Cornish, P.S. and Stewart, T.E.B. 2002. Certification – case studies with Australian market gardeners. In: Thompson, R. (ed.) *Cultivating Communities. Proceedings of the 14th IFOAM Organic World Congress*, 21–28 August 2002, Victoria, Canada. Canadian Organic Growers, Ottawa. p. 222.

Doing, H. 1997. The landscape as an ecosystem. *Agriculture, Ecosystems and Environment* 63(2–3): 221–225.

Drinkwater, L.E., Letourneau, D.K., Workneh, F., van Bruggen, A.H.C. and Shennan, C. 1995. Fundamental differences between conventional and organic tomato agroecosystems in California. *Ecological Applications* 5(4): 1098–1112.

Eckert, H., Breitschuh, G. and Sauerbeck, D.R. 2000. Criteria and standards for sustainable agriculture. *Journal of Plant Nutrition and Soil Science* 163(4): 337–351.

Edmeades, D.C. 2003. The long-term effects of manures and fertilisers on soil productivity and quality: a review. *Nutrient Cycling in Agroecosystems* 66(2): 165–180.

Gijsbers, G., Janssen, W., Hambly Odame, H. and Meijerink, G. (eds) 2001. *Planning Agricultural Research: A Sourcebook*. CAB International, Wallingford.

Githiori, J.B., Hoglund, J., Waller, P.J. and Baker, R.L. 2003. The anthelmintic efficacy of the plant, *Albizia anthelmintica*, against the nematode parasites *Haemonchus contortus* of sheep and *Heligmosomoides polygyrus* of mice. *Veterinary Parasitology* 116(1): 23–34.

Goldstein, W.A. and Barber, W. 2005. Yield and root growth in a long-term trial with biodynamic preparation. In: *Shaping Sustainable Systems. Proceedings of the 15th IFOAM Organic World Congress*. 20–23 September 2005, Adelaide Australia. IFOAM (International Federation of Organic Agriculture Movements), Bonn. CD-ROM.

Gosling, P. and Shepherd, M. 2005. Long-term changes in soil fertility in organic arable farming systems in England, with particular reference to phosphorus and potassium. *Agriculture, Ecosystems and Environment* 105: 425–432.

Goulding, K. 2000. Nitrate leaching from arable and horticultural land. *Soil Use and Management* 16(4): 145–151.

Greer, L. 2002. *Organic Plug and Transplant Production*. Appropriate Technology Transfer for Rural Areas, Fayetteville.

Guthman, J. 2000. *Agrarian Dreams: The Paradox of Organic Farming in California*. University of California Press, Berkeley.

Halberg, N., Alrøe, H.F. and Kristensen, E.S. 2005a. Synthesis: perspectives for organic agriculture in a global context. In: Halberg, N., Alrøe, H.F., Knudsen, M.T. and Kristensen, E.S. (eds) *Global Development of Organic Agriculture: Challenges and Promises*. CAB International, Wallingford. pp. 344–368.

Halberg, N., Sulser, T.B., Høgh-Jensen, H., Rosegrant, M.W. and Knudsen, M.T. 2005b. The impact of organic farming on food security in a regional and global perspective. In: Halberg, N., Alrøe, H.F., Knudsen, M.T. and Kristensen, E.S. (eds) *Global Development of Organic Agriculture: Challenges and Promises*. CAB International, Wallingford. pp. 277–322.

Harris, J.A. 2003. Measurements of the soil microbial community for estimating the success of restoration. *European Journal of Soil Science* 54(4): 801–808.

Helander, C.A. and Delin, K. 2004. Evaluation of farming systems according to valuation indices developed within a European network on integrated and ecological arable farming systems. *European Journal of Agronomy* 21(2): 53–67.

Hendriks, K., Stobbelaar, D.J. and van Mansvelt, J.D. 1997. Some criteria for landscape quality applied on an organic goat farm in Gelderland, the Netherlands. *Agriculture, Ecosystems and Environment* 63(2–3): 185–200.

IFOAM. 2002. *Final Draft 2002. Basic Standards for Organic Production and Processing*. IFOAM (International Federation of Organic Agriculture Movements), Tholey-Theley, Germany.

IFOAM. 2005. *International Federation of Organic Agriculture Movements Annual Report 2004*. International Federation of Organic Agriculture Movements, Bonn.

Ikerd, J. 1999. Specialized systems and the economic stakes. In: *Organic Agriculture Faces the Specialization of Production Systems*. Jack Cartier Center, Lyon France, December 6–9, 1999.

Ingham, R.E., Trofymow, J.A., Ingham, E.R. and Coleman, D.C. 1985. Interactions of bacteria, fungi, and their nematode grazers on nutrient cycling and plant growth. *Ecological Monographs* 55: 119–140.

Keatinge, R., Jackson, F., Kyriazakis, I. and Cork, S.A. 2002. Developing parasite control strategies in organic systems. In: Powell, J. (ed.) *Proceedings of the UK Organic Research 2002 Conference: Research in Context*. 26–28 March 2002, Aberystwyth. Organic Centre Wales, Institute of Rural Studies, University of Wales Aberystwyth, Aberystwyth. pp. 341–345.

King, C., Gunton, J., Freebairn, D., Coutts, J. and Webb, I. 2000. The sustainability indicator industry: where to from here? A focus group study to explore the potential of farmer participation in the development of indicators. *Australian Journal of Experimental Agriculture* 40(4): 631–642.

Kirchmann, H. and Ryan, M.H. 2004. Nutrients in organic farming – are there advantages from the exclusive use of organic manures and untreated minerals? In: Fischer, T., Turner, N., Angus, J., McIntyre, L., Robertson, M., Borrell, A. and Lloyd, D. (eds) *New directions for a diverse planet. Proceedings of the 4th International Crop Science Congress*. 26 Sept.–1 Oct. 2004, Brisbane, Australia. The Regional Institute, Gosford. pp. CD-ROM.

Köpke, U. 2005. Organic agriculture: maintaining old principles in a changing environment? In: IFOAM (ed.) 2005. *Shaping Sustainable Systems. Proceedings of the 15th IFOAM Organic World Congress*. 20–23 September 2005, Adelaide Australia. International Federation of Organic Agriculture Movements, Bonn.

Kuiper, J. 1997. Organic mixed farms in the landscape of a brook valley. How can a co-operative of organic mixed farms contribute to ecological and aesthetic qualities of a landscape? *Agriculture, Ecosystems and Environment* 63(2–3): 121–132.

Lampkin, N. 1990. *Organic Farming*. Farming Press, Ipswich.

Lieblein, G., Østergaard, E. and Francis, C. 2005. Becoming an agroecologist through action education. *International Journal of Agricultural Sustainability* 2(3): 147–153.

Lohr, L. 2005. Economic, social, and environmental benefits associated with US organic agriculture. In: Köpke, U., Niggli, U., Neuhoff, D., Cornish, P., Lockeretz, W. and Willer, H. (eds) *Researching Sustainable Systems. Proceedings of the First Scientific Conference of the International Society of Organic Agriculture Research (ISOFAR), Held in cooperation with the International Federation of Organic Agriculture Movements (IFOAM) and the National Association for Sustainable Agriculture, Australia (NASAA)*. 21–23 September 2005, Adelaide Convention Centre, Adelaide, Australia. International Society of Organic Agriculture Research, Institute of Organic Agriculture and Research Institute of Organic Agriculture, Bonn and Frick. pp. 446–449.

Lotter, D.W. 2003. Organic agriculture. *Journal of Sustainable Agriculture* 21(4): 59–128.

Lotter, D.W., Seidel, R. and Liebhardt, W. 2003. The performance of organic and conventional cropping systems in an extreme climate year. *American Journal of Alternative Agriculture* 18(3): 146–154.

Mäder, P., Fließbach, A., Dubois, D., Gunst, L., Fried, P. and Niggli, U. 2002. Soil fertility and biodiversity in organic farming. *Science* 296(5573): 1694–1697 (and supplementary material).

Manici, L.M., Caputo, F. and Babini, V. 2004. Effect of green manure on *Pythium* spp. population and microbial communities in intensive cropping systems. *Plant and Soil* 263(1): 133–142.

Martini, E.A., Buyer, J.S., Bryant, D.C., Hartz, T.K. and Denison, R.F. 2004. Yield increases during the organic transition: improving soil quality or increasing experience? *Field Crops Research* 86: 255–266.

Millennium Ecosystem Assessment 2005. *Millennium Ecosystem Assessment Synthesis Report*. Island Press, Washington DC.

Neeson, R. and Howell, G. 2003. *National Organic Seed and Seedling Production Workshops Report*. Rural Industries Research and Development Corporation, Barton.

Nyeko, P., Edwards-Jones, G., Day, R.K. and Raussen, T. 2002. Farmers' knowledge and perceptions of pests in agroforestry with particular reference to *Alnus* species in Kabale district, Uganda. *Crop Protection* 21(10): 929–941.

OECD (ed.) 1999. *Environmental Indicators for Agriculture: Vol. 1: Concepts and Framework*. Organisation of Economic Cooperation and Development, Paris.

Pannell, D.J. and Glenn, N.A. 2000. A framework for the economic evaluation and selection of sustainability indicators in agriculture. *Ecological Economics* 33(1): 135–149.

Parrott, N., Olesen, J.E. and Høgh-Jensen, H. 2005. Certified and non-certified organic farming in the developing world. In: Halberg, N., Alrøe, H.F., Knudsen, M.T. and Kristensen, E.S. (eds) *Global Development of Organic Agriculture: Challenges and Promises*. CAB International, Wallingford.

Pearce, B., Stopes, C., Lennartsson, M., Manchett, R., Kennedy, R. and Clarkson, J. 2000. Organic vegetable transplants: evaluation and development of production techniques. In: Alföldi, T., Lockeretz, W. and Niggli, U. (eds) *IFOAM 2000 - The World Grows Organic. Proceedings of the 13th International IFOAM Scientific Conference*. Convention Centre Basel, Switzerland 28 to 31 August 2000. vdf Hochschulverlag AG an der ETH Zurich, Basel. p. 198.

Pender, J. and Mertz, O. 2005. Soil fertility depletion in Sub-Saharan Africa: what is the role of organic agriculture? In: Halberg, N., Alrøe, H.F., Knudsen, M.T. and Kristensen, E.S. (eds) *Global Development of Organic Agriculture: Challenges and Promises*. CAB International, Wallingford.

Penfold, C. 2000. *Phosphorus Management in Broadacre Organic Farming Systems*. Rural Industries Research and Development Corporation, Barton.

Pretty, J., Ashby, J., Ball, A., Morison, J. and Uphoff, N. 2003. Editorial. *International Journal of Agricultural Sustainability* 1(1): 1–2.

Raupp, J. 1999. Biodynamic approaches in research and development. In: Zanoli, R. and Krell, R. (eds) *First SREN Workshop on Research Methodologies in Organic Farming. Proceedings*. Frick, Switzerland. 30 September–3 October 1998. Food and Agriculture Organization of the United Nations, Rome. pp. 41–47.

Reed, M. 2003. *Servants of the Soil: The Lonely Furrow of the Soil Association 1946-2000*. Centre for Rural Research, University of Exeter, Exeter.

Reganold, J.P. 1995. Soil quality and profitability of biodynamic and conventional farming systems: a review. *American Journal of Alternative Agriculture* 10(1): 36–45.

Ridley, A.M. 2005. The role of farming systems group approaches in achieving sustainability in Australian agriculture. *Australian Journal of Experimental Agriculture* 45(6): 603–615.

Ridley, A.M., Paramore, T.R., Beverly, C.R., Dunin, F.X. and Froelich, V.M.C. 2003. Developing environmental monitoring tools from sustainability indicators in the southern Riverina. *Australian Journal of Experimental Agriculture* 43(3): 271–284.

Roberts, W.S. and Swinton, S.M. 1996. Economic methods for comparing alternative crop production systems: a review of the literature. *American Journal of Alternative Agriculture* 11(1): 10–17.

Rösch, C. 2006. Using modern technologies in organic farming. *Ecology and Farming* 39: 45.

Ryan, M. and Ash, J. 1999. Effects of phosphorus and nitrogen on growth of pasture plants and VAM fungi in SE Australian soils with contrasting fertiliser histories (conventional and biodynamic). *Agriculture, Ecosystems and Environment* 73(1): 51–62.

Sena, M.M., Frighetto, R.T.S., Valarini, P.J., Tokeshi, H. and Poppi, R.J. 2002. Discrimination of management effects on soil parameters by using principal component analysis: a multivariate analysis case study. *Soil and Tillage Research* 67(2): 171–181.

Sligh, M. and Christman, C. 2003. *Who Owns Organic? The Global Status, Prospects and Challenges of a Changing Organic Market*. Rural Advancement Foundation International–USA, Pittsboro.

Steenwerth, K.L., Jackson, L.E., Calderon, F.J., Stromberg, M.R. and Scow, K.M. 2003. Soil microbial community composition and land use history in cultivated and grassland ecosystems of coastal California. *Soil Biology and Biochemistry* 35(3): 489–500.

Stirzaker, R., Lefroy, T., Keating, B. and Williams, J. 2000. *A Revolution in Land Use: Emerging Land Use Systems for Managing Dryland Salinity*. CSIRO Land and Water, Dickson.

Stoneham, G., Eigenraam, M., Ridley, A. and Barr, N. 2003. The application of sustainability concepts to Australian agriculture: an overview. *Australian Journal of Experimental Agriculture* 43(3): 195–203.

Sulser, T.B., Duryea, M.L., Frolich, L.M. and Guevara-Cuaspud, E. 2001. A field practical approach for assessing biophysical sustainability of alternative agricultural systems. *Agricultural Systems* 68(2): 113–135.

Svensson, K. and Pell, M. 2001. Soil microbial tests for discriminating between different cropping systems and fertiliser regimes. *Biology and Fertility of Soils* 33(2): 91–99.

Tafuna'i, A.M. 2005. Technology, tradition & trade sustainable rural economies. In: *Shaping Sustainable Systems. Proceedings of the 15th IFOAM Organic World Congress*. 20–23 September 2005, Adelaide Australia. IFOAM (International Federation of Organic Agriculture Movements), Bonn. CD-ROM.

Thirsk, J. 2000. *Alternative Agriculture: A History. From the Black Death to the Present Day.* Oxford University Press, Oxford.

Tillett, N.D., Hague, T. and Miles, S.J. 2002. Inter-row vision guidance for mechanical weed control in sugar beet. *Computers and Electronics in Agriculture* 33(3): 163–177.

Tilman, D. 1999. Global environmental impacts of agricultural expansion: the need for sustainable and efficient practices. *Proceedings of the National Academy of Sciences of the United States of America*. 96(11): 5995–6000.

Trejo-Estrada, R., Rivas Sepulveda, I. and Crawford, D.L. 1998. *In vitro* and *in vivo* antagonism of *Streptomyces violaceusniger* YCED9 against fungal pathogens of turfgrass. *World Journal of Microbiology and Biotechnology* 14(6): 865–872.

Trenbath, B.R. 1999. Multispecies cropping systems in India: predictions of their productivity, stability, resilience and ecological sustainability. *Agroforestry Systems* 45(1–3): 81–107.

Trewavas, A. 2001. Urban myths of organic farming. *Nature* 410: 409–410.

Trewavas, A. 2004. A critical assessment of organic farming-and-food assertions with particular respect to the UK and the potential environmental benefits of no-till agriculture. *Crop Protection* 23(9): 757–781.

van de Ven, G.W.J., de Ridder, N., van Keulen, H. and van Ittersum, M.K. 2003. Concepts in production ecology for analysis and design of animal and plant-animal production systems. *Agricultural Systems* 76(2): 507–525.

Vazquez, R.I., Stinner, B.R. and McCartney, D.A. 2003. Corn and weed residue decomposition in northeast Ohio organic and conventional dairy farms. *Agriculture, Ecosystems and Environment* 95(2–3): 559–565.

Vereijken, J.F.H.M., van Gelder, T. and Baars, T. 1997. Nature and landscape development on organic farms. *Agriculture, Ecosystems and Environment* 63(2–3): 201–220.

Vogt, K.A., Beard, K.H., Hammann, S., O' Hara Palmiotto, J., Vogt, D.J., Scatena, F.N. and Hecht, B.P. 2002. Indigenous knowledge informing management of tropical forests: the link between rhythms in plant secondary chemistry and lunar cycles. *Ambio* 31(6): 485–490.

Wardle, D.A., Giller, K.E. and Barker, G.M. 1999. The regulation and functional significance of soil biodiversity in agroecosystems. In: Wood, D. and Lenné, J.M. (eds) *Agrobiodiversity: Characterization, Utilization, and Management*. CABI Publishing, Wallingford. pp. 87–121.

Welbaum, G.E., Sturz, A.V., Dong, Z. and Nowak, J. 2004. Managing soil microorganisms to improve productivity of agro-ecosystems. *Critical Reviews in Plant Sciences* 23(2): 175–193.

Welsman, S. 2001. *Keeping Sheep Alive. Sustainable Control of Internal Parasites in Sheep (SCIPS) Program Review*. Australian Wool Innovation, Sydney.

White, R.E. 2005. Vegetable module propagation – the transition from a conventional propagation system to organic propagation. In: *International Congress on Organic Farming, Food Quality and Human Health*. Newcastle upon Tyne, UK, 6–9 January 2005. University of Newcastle upon Tyne, Newcastle. <http://www.qlif.org/qlifnews/april05/con3.html#Anchor-Vegetabl-558>. Accessed 17/1/06.

Willer, H. and Yussefi, M. (eds) 2005. *The World of Organic Agriculture 2005 - Statistics and Emerging Trends*. International Federation of Organic Agriculture Movements, Bonn.

Wood, S., Sebastian, K. and Scherr, S.J. 2001. *Pilot Analysis of Global Ecosystems: Agroecosystems*. World Resources Institute, Washington DC.

Woodward, L. and Vogtmann, H. 2004. IFOAM's Organic Principles. *Ecology and Farming* 36: 24–26.

Wynen, E. 2003. *Organic Agriculture in Australia - Levies and Expenditure*. Rural Industries Research and Development Corporation, Barton.

Youngs, G.A., Goreham, G.A. and Watt, D.L. 1991. Classifying conventional and sustainable farmers: does it matter how you measure? *Journal of Sustainable Agriculture* 2(2): 91–115.

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