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CORRELATION OF CHERNOZEMS CLASSIFICATION IN WRB AND NATIONAL SLOVAK SOIL CLASSIFICATION SYSTEM

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This paper provides information on classification of chernozems in Slovak national soil classification and discusses the problems of its correlation with WRB. The preparation of correlation scheme for converting particular chernozem categories used in Slovak classification to categories used in WRB enabled to compare general concepts and particular criteria of both classification systems, to identify major problems of conversion resulting from different classification philosophy and different quantitative classification criteria and finally to discuss the possible ways how to overcome them.
Keywords: Chernozems, classification of chernozems, mollisols, classification of mollisols, WRB, Slovak soil classification

Introduction. Chernozems occupy significant portion of Slovak lowlands and due to their high fertility and large acreage they belong to most important agricultural soils of Slovakia. The most significant investigations of chernozems were carried in 1960ties when General Soil Survey of former Czechoslovakia brought a lot of new information about all agricultural soils of Slovakia. In this period several key papers and books on chernozems were published [1, 6, 7, 13] and the Slovak national concept of chernozems was fixed. This concept corresponded in general to original Russian concept of chernozems as it was presented by Dokuchajev [3, 4] and many other studies but it reflected also some specific features of Slovak chernozems: 1) Slovak chernozems are soils developed under steppe vegetation dominating in Slovak lowlands during dry period of early Holocene and later they were protected from "degradation" under the forest thanks to agriculture which substituted the "steppe conditions" and prevented the invasion of forests; 2) Slovak chernozems are different from typical chernozems in Russia and Ukraine, they are less developed (less thick and less dark) because they are developed in the periphery of continental steppe area, where the steppe conditions are less pronounced.

Since 1970 the origin, characterization and evaluation of chernozems was considered as more or less closed question. Occasional studies published later usually did not cross the conventional understanding of chernozems of Slovakia fixed in 1960ties and they were carried within relatively narrow geographical limits of lowlands in Danube Basin. The exception was the study of Linkeš [12], who introduced a hypothesis of hydromorphic and geological factors as major factors determining the chernozem formation. This paper, however, did not attract much attention of scientific community and did not change the general concept of Slovak chernozems. New impulse to investigation of chernozems came in second half of 1990ies and in 2000s. Along with significant changes of national soil classification which switched its basic pedogenetic concept towards morphometric concept [8], and subsequent quick development of new approximations of morphogenetic classification [9, 15], the definition of chernozems, while still following the general concept set in the 1960ies, was made more detailed and exact.

Major objective of this paper is to provide basic information on classification criteria of chernozems in Slovak national soil classification and based on this to suggest exact correlation scheme for converting particular chernozem categories used in Slovak national classification to categories used in World Reference Base for Soil Resources [11] (further referred as WRB) and to identify and discuss the major problems resulting from differences of general concepts and particular criteria of both classification systems.

Object and methods. *Chernozems in Slovakia.* Most significant areas of chernozems in Slovakia can be found in large lowland (*Podunajská nížina*) occupying south-western part of the country. Several other minor areas occur in other major lowlands (*Borská nížina* in wester Slovakia and *Východoslovenská nížina* in Eastern Slovakia and in southernmost inner Carpathian basins (*Rimavská kotlina* and *Košická kotlina*). (Fig. 1). Most of Slovak chernozems developed on loess, alluvial sediments and eolian sands. The loam, silty loam, silty clay loam or silty clay textured loess is a parent material of chernozems in hilly lands of *Podunajska nížina*, *Záhorská nížina* and *Východoslovenská nížina* lowlands; loam, silty loam or silty clay loam textured alluvial sediments (flood sediments and most likely also re-washed loess) are parent material of chernozems at flat alluvial plane of *Podunajská nížina* and *Východoslovenská nížina* lowlands and Pleistocene terraces of *Rimavská kotlina* inner Carpathian basin; and calcareous aeolian sands of loamy sand and sand textures are parent materials of chernozems developed at some few sand dunes scattered in *Podunajska nížina* lowland.

Significant feature of some chernozems in Slovakia is presence of calcium carbonates in surface mollic horizons both in form of microcristaline impregnation of soil matrix not visible by unaided eye and in macromorphological forms such as pseudomycelia (soft accumulations in pores built by needle calcite) and hard nodules [6, 7]. Features of hydromorphic development (usually rusty mottles of redistributed oxidized iron, sometimes also iron depleted reduction features) are evident in soil profiles of some chernozems in Danube alluvium [7]. Chernozems at *Podunajská nížina* lowland form a topoclimasequence with increasing depth of decalcification towards the mountains as described by Mičian and Bedrna [13], and Bedrna [1]. A bit different pattern is developed in the *Východoslovenská nížina* lowland, where chernozems are more leached of calcium carbonates and more influenced by subsurface water [2].

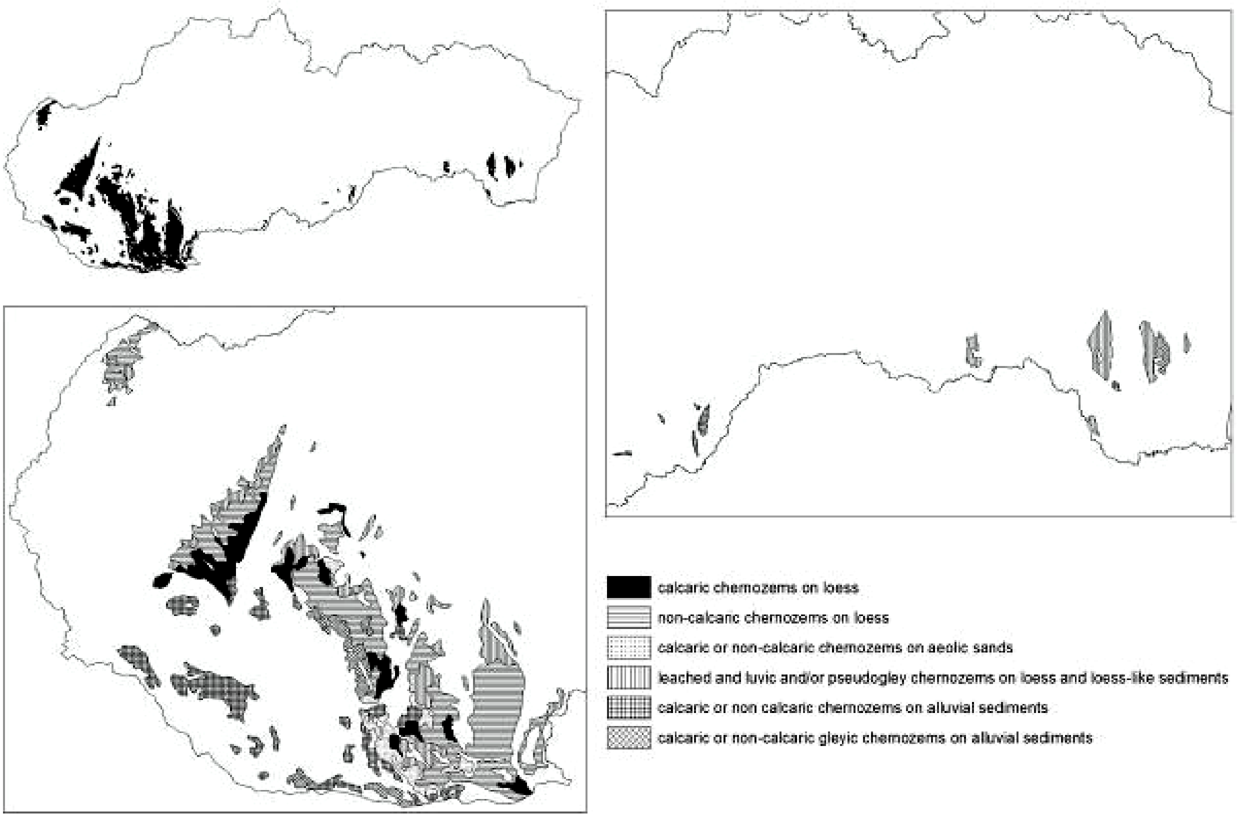

Fig. 1. Spatial distribution of chernozems in Slovakia (after Hraško et al., [10])

Soil classification system of Slovakia. Although the problem of evaluation and classification of chernozems attracted some attention in Slovakia already in 2nd half of 18th century and the basis of the genetic soil classification were laid during the first half of 20th century adopting the pedogeographic and pedogenetic principles of Russian pedological school, as well as the territorial extension of chernozems was approximately known already that time the first soil classification having continual importance until today is that of Němeček at al. [14] used for compilation of large and medium scale soil maps during the General Soil Survey of agricultural soils of former Czechoslovakia in 1961 – 1970 period. Genetic classification had four-taxonomical levels. At first three levels the soil classification was based on combination of genetic horizons and at the lowest level the soil parent material, texture and stoniness were used.

Late 1980ies brought an important milestone of the soil classification evolution. After many decades of domination of genetic classification a first morphogenetic soil classification system was published by Hraško et al. [8]. New system involved both agricultural and forests soils. Soon it was revised (Hraško et al. [9]. The system comprised of five taxonomic levels; the lowest level of taxonomic system was further specified by soil parent material and texture. Genetic principles of soil classification took place at the highest level (soil groups); the lower levels followed exactly defined morphometric criteria for classification of diagnostic horizons, soil types and subtypes (combination of diagnostic soil horizons), soil varieties (significant chemical properties of soil) and soil forms (erosion/accumulation, anthropic influence).

So far, the last version of national soil classification system of Slovakia was published by *Societas Pedologica Slovaca* in 2000 [15]. This last approximation of Morphogenetic soil classification system of Slovakia (further referred as MSCSS) follows the classification principles of the former version [9] and its hierarchy of the taxonomic levels and principles of their definition. Most significant change from the previous version is introduction of diagnostic soil properties into the system, refinement of the most of soil diagnostic horizon definitions and reconsideration of soil classification into the soil groups. Actually, MSCSS is the generally accepted national Slovak reference for classification both agricultural and forest soils.

Classification criteria for chernozems in MSCSS. Definitions of chernozems by WRB are easy accessible from various public domains and therefore only their classification by MSCSS are described below.

In total, twelve soil groups can be distinguished on the highest taxonomic level of MSCSS. Chernozems are classified in *soil group* of *mollic soils*. MSCSS defines *mollic soil group* as a group of soils having mollic horizon and lacking any other fully developed diagnostic horizon with only exception of gleyic diagnostic horizon. Three *soil types* are distinguished in mollic soil group: 1) *smonica*, 2) *černozem*, and 3) *čiernica*, from which only *černozem* stands for chernozems in the narrowest meaning. Remaining soil types *smonica* and *čiernica* stand for mollic soils having vertic properties and mollic soils having developed under significant hydromorphic conditions, respectively.

Although some MSCSS soil taxonomic units of other than *černozems* could be classified as *Chernozems* in WRB, here we concern only soil type of *černozem* because discussion of all other soil taxonomic classes would go beyond the scope of this article. Therefore soil types of *smonica* and *čiernica* from mollic soil groups and mollic subtypes of *slanec* and *solončak* soil types from salinic soil group are not considered in this description.

Chernozems (*černozem*) are in MSCSS defined as soils having mollic surface horizon with or without content of calcium carbonates which developed from unconsolidated parent materials.

Mollic horizon (Am) is defined as dark, well-structured surface horizon saturated by bases having:

a) thickness more than 10 cm;
b) humus content from 1 to 30 %;
c) moist color value less than 3.5 and chroma less than 3.5; dry color value less than 5.5; and when moist the value at least one degree and chroma at least two degree darker than underlying substrate horizon;
d) base saturation of more than 50%;
e) and at least one of the following:

- portion of Ca (Mg, Al, Fe) bounded humic acids of at least 40% of total humic acids content;
- humic acids to fulvic acids ratio higher than 1;

– portion of bounded humic acid to free humic acids equal or higher than 3;
– portion of free humic acids from total humic acids lower than 20 %;
– color quotient Q4/6 equal or lower than 3 for humic acids and equal or lower than 4 for all humic substances;
– organic carbon to organic nitrogen ratio of 12 or less.

Černozem soil type is subdivided to several subtypes characterized by evidences of soil forming processes other than organic matter accumulation. The use of subtypes in soil classification is not exclusive and more than one subtype specification can be used to classify the soil. Subtypes of chernozems (*černozem*) are defined as follows.

a) ***Typical chernozem*** (*černozem modálna*) no other dignostic horizons or features of other soil forming processes;
b) ***Cultivated chernozem*** (*černozem kultizemná*) having plough diagnostic horizon (Akp) down to a maximum depth of 35 cm which is characterized by having features of soil cultivation such as homogenization of the upper soil layer, abrupt transition to underlying horizon, compaction of layer directly underlying the plowed horizon, lighter color than underlying horizon, or some traces of liming or fertilizers and manure application;
c) ***Brown chernozem*** (*černozem hnedozemná*) having some features of clay illuviation under the mollic horizon (at least some clay coatings in transition A/C horizon), but lacking Luvic diagnostic horizon (Bt);
d) ***Luvic chernozem*** (*černozem luvizemná*) having ***luvic diagnostic horizon*** below the mollic horizon defined as soil horizon of illuvial accumulation of translocated clay having 1) thickness of more than 15 cm, 2) increase in content of the particles smaller than 0.002 mm as compared to overlying horizont depleted of clay within depth interval of 30 cm of 3, 20 or 8 % for the soils with clay content of less than 15%, 15 – 40%, or more than 40 %, respectively, 3) soil pores filled or at least 10% of soil aggregates covered by oriented clay coatings, and 4) exchangeable Na content of less than 5%, free iron content of less than 2.5 %, and both organic matter content of less than 1 % and not more than 50 % of organic matter content of the overlying A horizon;
e) ***Cambic chernozem*** (*černozem kambizemná*) having features of brunification (alteration) such as reddish color, better developed soil structure, increase in clay content as compared to underlying or upper horizons, or at least carbonates are totally leached from transition A/C horizon;
f) ***Gleyic chernozem*** (*černozem čiernicová*) having oxidation features of gley diagnostic horizon Go in substrate horizon starting within 100 cm from soil surface (10 % or more of Fe-Mn impregnations or accumulations in soil matrix resulted from temporal saturation of soil by capillary water, less than 10 % of reduction pattern in the soil);
g) ***Salic chernozem*** (*černozem slanisková*) having some features of readily soluble salts accumulation in soil profile (EC 4 – 15 mS/cm, or 0.3 – 1% content of readily soluble salts if soil pH (in H_2O) is less than 8.4).

At next classification level ***soil varieties*** are distinguished in order to express some specific features of soil chemism, particularly the carbonate content in surface horizon or contamination of soil by inorganic contaminants. Thus for each of above mentioned subtypes the ***carbonate variety*** and ***contaminated variety*** can be distinguished.

The lowest classification level of ***soil form*** is dedicated to express the possible impact of soil erosion and accumulation processes. ***Eroded*** or ***accumulated forms*** of chernozems reflect the presence of signs of anthropogenic erosion or accumulation in the soil profile; or fluvial accumulation in the case of chernozems developed on alluvial sediments.

Results and their discussion. The comparison of the chernozems expressed in MSCSS and WRB is given in Tab 1. The table is constructed in the way it emphasizes some problematic definitions in WRB with regard to the Slovak chernozems. These are more rigorous moist soil color criteria for *mollic* horizon of chernozems and fluvial sediments having features of *fluvic* material as parent material of some chernozems.

Moist soil color criteria for *mollic* horizon seem to be the most problematic with regard to Slovak chernozems classification in WRB. Application of this criteria implies that soils of very similar morphological properties (with only exception of color) having very similar position and performance within the ecosystem and being often also geographically located in close vicinity are classified as two different soil types – ***Chernozems*** and ***Phaeozems***.

1. Approximate comparison of the Slovak chernozems definition in MSCSS and WRB classification.

Subtype of chernozem according MSCSS	Classification by WRB (no suffix qualifiers assumed)			
	no fluvic material		fluvic material	
	chroma < 2	chroma > 2	chroma < 2	chroma > 2
Typical chernozem (*černozem modálna*)	Haplic Chernozem	Haplic Phaeozem	Endofluvic Chernozem /Mollic Fluvisol	Mollic Fluvisol
Cultivated chernozem (*černozem kultizemná*)	Haplic Chernozem	Haplic Phaeozem	Endofluvic Chernozem /Mollic Fluvisol	Mollic Fluvisol
Brown chernozem (*černozem hnedozemná*)	Calcic Chernozem	Calcic Phaeoozem	-	-
Luvic chernozem (*černozem luvizemná*)	Luvic Chernozem	Luvic Phaeozem	-	-
Cambic chernozem (*černozem kambizemná*)	Calcic Chernozem	Calcic Phaeozem	-	-
Gleyic chernozem (*černozem čiernicová*)	(Endo-, Epi-) gleyic Chernozem	(Endo-, Epi-) gleyic Phaeozem	(Endo-, Epi-) gleyic Endofluvic Chernozem /Mollic (Endo-,Epi-)gleyic Fluvisol	Mollic (Endo-, Epi-) gleyic Fluvisol
Salic chernozem (*černozem slanisková*)	Endosalic Chernozem	Endosalic Phaeozem	Endosalic Endogleyic Chernozem /Mollic Salic Fluvisol	Mollic Salic Fluvisol

The second item for discussion is an emphasis of climate and vegetation soil-forming conditions of *Chernozems* and *Phaeozems* in WRB, [11] p. 76 and p. 88. This could be, however, not completely true for Slovak [7, 12], or Central European chernozems [5] as chernozems in Central Europe have developed in area at transition between continental and oceanic climate and the steppe conditions were not so pronounced here. The reason of the observed differences in soil morphology (soil color for instance) could have been caused also by some other factors than zonal change of soil-forming factors usually reported for large regions of Eurasia or Northern America having well developed soil zonality. Strict referring to climate and vegetation conditions as defined in WRB may bias the interpretations of geographical conditions of Slovakia.

The third item for discussion is the problem of *fluvic* material as parent material of chernozems, although it does not seems to be too important. Most of the Slovak chernozems developed from alluvial sediments can be classified as *Chernozems* and further specified by *Endofluvic* qualifier. A bit problematic with regard to *fluvic* material as parent material of chernozems having light-colored *mollic* horizons seems to be the fact that for *Phaeozems* there is not explicitly listed *Endofluvic* qualifier and all soils having *fluvic* material have to be classified in *Fluvisols* reference group.

Conclusions. Chernozems of Slovakia have some genetic and morphological particularities well reflected in national soil classification system of Slovakia (MSCSS, [15]). The comparison of chernozems classification in MSCSS and WRB showed that both classification systems can be correlated. The conversion table which resulted from the comparison of both classifications can be used as a practical tool for quick conversion of information stored in national databases. Alongside with that the comparison enabled to identify few particular problems of such conversion resulting from some differences of diagnostic criteria. The problem points are following:

- More strict moist soil color criteria (chroma 2 or less) of *mollic* horizon used for *Chernozem* definition in WRB split Slovak chernozems if classified according to WRB into *Phaeozems* and *Chernozems*;
- The concept of chernozem as strictly climazonal soil adopted in WRB does not provide a realistic picture of the origin of Slovak chernozems;
- Different concept of soils developed from fluvial deposits affects the conversion of chernozems developed from fluvial deposits. A bit problematic seems to be the fact that for *Phaeozems* there is not explicitly listed *Endofluvic* qualifier and some chernozems developed at alluvial planes and having moist color value higher than 2 are falling to *Mollic Fluvisols*.

Regardless the abovementioned problems we can conclude that WRB system can be successfully used as reference for exchange of information on soil between national (Slovak) and international scientific community. With this respect it is important to keep in the mind the identified differences of some classification criteria.

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КОРЕЛЯЦІЯ КЛАСИФІКАЦІЇ ЧОРНОЗЕМІВ У WRB ТА НАЦІОНАЛЬНІЙ СЛОВАЦЬКІЙ КЛАСИФІКАЦІЙНІЙ СИСТЕМІ

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Наведена інформація щодо класифікації чорноземів у Словацькій національній класифікаційній системі та обговорені проблеми кореляції з WRB. Запропонована кореляційна схема, що дозволяє розглядати специфічні категорії чорноземів у національній класифікації з позиції WRB, дає можливість порівнювати загальні поняття і специфічні критерії, ідентифікувати головні проблеми перетворення з огляду на різну філософію класифікацій та неуніфікованість кількісних критеріїв. Визначені шляхи подолання зазначених труднощів.
Ключові слова: чорноземи, класифікація чорноземів, молісолі, класифікація молісолей, WRB, Словацька класифікація грунтів