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POSITION OF TECHNOSOLS IN THE SLOVAK SOIL CLASSIFICATION SYSTEM AND THEIR CORRELATION

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The newly established Technosols involved in the latest issue of WRB 2006 have been correlated with Anthrozems which can be considered as analogues to these soils in the Slovak soil classification system. Such correlation can be helpful in highlighting the essential differences in soil properties and finding the main classification criteria of these soils. Moreover, this process can facilitate further development and refinement of classification criteria. Detailed diagnostic features of both soil types have been recognized and correlated each to other.

Keywords: soil classification, correlation, Anthrozem, Technosol, WRB 2006, MSCS 2000.

Я. Собоцка

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ПОЛОЖЕННЯ TECHNOSOLS У СЛОВАЦЬКІЙ СИСТЕМІ КЛАСИФІКАЦІЇ ҐРУНТІВ І ЇХ КОРЕЛЯЦІЇ

Недавно встановлені *Technosols*, введені в останнє видання *WRB* 2006, були корельовані з *Anthrozems*, які можна розглядати як аналоги цим ґрунтам у словацькій системі класифікації ґрунтів. Така кореляція може бути корисною у висуванні на перший план суттєвих розходжень у властивостях і виявленні головних критеріїв класифікації цих ґрунтів. Крім того, цей процес може полегшити подальший розвиток й обробку критеріїв класифікації. Детальні діагностичні особливості обох типів ґрунтів були вивчені й корельовані одні з іншими.

Ключові слова: класифікація ґрунтів, кореляція, Anthrozem, Technosol, WRB 2006, MSCS 2000.

A lot of soil scientists over the world encounter in definition and classification so-called man-made soils. Here they have found many various interpretations following very divergent classification concepts. In many soil classification systems terms such as anthropogenic soil, urban soil, man-made soil, artificial soil, cultivated soil, etc. are perceived by soil scientists very variously, and those different scientific terms can be confusing. Also defining and classifying such soils leads to various interpretations due to diverse classification concepts. In many cases, man-made soils are classified according to natural soil classification for example Regosols, Rendzinas, etc. in German classification concept (DBG, 1998) or Entisols and/or Inceptisols in Soil Taxonomy (Ahrens, Engel, 1999). Also they can be recognized as technogenic superficial formations in the Russian classification concept (Tonkonogov, Lebedeva, 1999), Anthroposol (artificial or reconstructed) in the French classification system (Blaize, 1998.), Urbanozems in Stroganova et al. (1998) and or like Anthrozems in the Slovak classification system (Sobocka, Bedrna, Jurani, Račko, 2000). These soils are unique by the fact that in some (or many) soil classification systems are not considered as soils, they are presented like soil bodies, or artificial soils or substrate soils. General definition of these soils is not yet clear.

First proposal explaining terminological situation in urban soils and anthropogenic soils has been provided by Sobocka (2003) aiming to find internationally acceptable consensus. The term «urban soil» has been involved by Burghardt (1994) as a general terminological concept for soils occurring in urbanized, industrial, traffic and mining areas. The main reason for their differences from other soils is their position (location) in these specific areas. These soils are easily clustered according to the environment in which they have been developed. The term «anthropogenic soil» is considered as a general terminological classification concept respecting anthropogenic soil like classified individual (unit). It is a result of soil classification process in which grouping of soil individuals into more or less homogeneous groups respecting defined objectives is done.

However, it has been for a long time recognized that soils are natural bodies with properties resulting from their natural pedogenesis, i.e. grouping of individuals has been based on natural properties. Only in the last decade we can observe new ideas in which technical or technogenic impact of humans on soil has to be resulted in changed soil properties. Most soils in the city are intensively used and therefore permanently exposed to human influence (Rossiter, 2007). The numerous measurements and evaluation of soil properties carried out in urban environment support this opinion. Many of these properties can be regarded like extreme and do not occur in the nature. It can be noted that processes in these soils often differ from those in rural soils. Contamination by many pollutants are often much

higher, parent material is very diverse and often have extreme chemical composition. Soils from technical materials such as industrial wastes often experience rapid weathering unlike that in natural soils (Lehmann, Schad, 2007; Lehmann, Stahr, 2007). Therefore new definition had to be found in order to describe, classify and map soils in urban areas.

OBJECTS AND METHODS

Classification criteria principles of the Morphogenetic Soil Classification System of Slovakia (Collective, 2000) (further like MSCS 2000) and World Reference Base for Soil Resources (IUSS Working Group WRB, 2006) (further like WRB 2006) have been applied for correlation especially of Anthrozems and Technosols soil types. The correlative methodology was used for finding analogue or similar soil properties and highlights the main classification differences, of both classification systems. Also the first definition of both soil types was recognized.

Soil classification the MSCS 2000 includes one anthropogenic soils group that shelter two entirely diverse soils: Kultizems (cultivated soils) and Anthrozems (man-made soils). The principle of Kultizem's soil group diagnostics is profound transformation of the soil profile «in situ» by deep tillage, trenching, cultivation, fertilizers application and other agricultural practices (many features are similar to Anthrosols in WRB 2006, but not all are refined by the same way). Anthrozems in the MSCS 2000 are perceived like man-made soils with Anthrozemic diagnostic Ad-horizon developing from anthropogenic material. The differentiation criterion for Anthrozem diagnostics is transported (removed) materials called «anthropogenic material». This «ex-situ» substrate material is divided into three subgroups: with natural, natural-technogenic and technogenic provenance according to Sobocka et al. (2000). Their occurrence does not correspond with climatic, geologic, geomorphologic, nor pedological conditions of the site, but depends upon artificial (anthropic) transport and deposits Anthrozems are soils having Ad-horizon is characterized by: (i) thickness of > 1 cm, or (ii) organic carbon content > 0.3 %, or (iii) possible presence of artefacts (brick, pottery fragments, glass, plastic materials, iron, slag, coal, etc.). The thickness of anthropogenic materials must be > 35 cm. As varieties of the horizon are anthrozemic, initial Adi-horizon (< 10 cm) representing primitive stage of soil forming process from anthropogenic substrata, and anthrozemic recultivated Adr-horizon having evidence of recultivated measures supporting vegetation growth.

In the MSCS 2000 also contaminated Ax-horizon is defined for soils affected by exceeded contents of toxic or emission elements or compounds and can be used for Anthrozems description, too.

Technosols in the WRB 2006 classification concept are soils having: (i) 20 percent or more (by volume, by weighted average) artifacts in the upper 100 cm from the soil surface or continuous rock or a cemented or indurated layer, whichever is shallower, or (ii) a continuous, very slowly permeable to impermeable, constructed geomembrane of any thickness staring within 100 cm of the soil surface, or (iii) technic hard rock staring within 5 cm of the soil surface and covering 95 percent or more of the horizontal extent of the soil.

Artefacts as diagnostic material are solid or liquid substances that are:

1. created or substantially modified by humans as a part of an industrial or artisanal manufacturing process, or brought to the surface by human activity from a depth where they were not;
2. Have substantially the same properties as when first manufactured, modified or excavated.

Examples are: bricks, pottery, glass, crushed or dressed stone, industrial waste, garbage, processed oil products, mine spoil and crude oil.

Parent materials are all kinds of materials made or exposed by human activity that otherwise would not occur at the Earth's surface, pedogenesis of these soils is affected strongly by materials and their organization. Soil can be found mostly in urban and industrial areas; in small areas although in complex pattern can be associated with other groups. Profile development is generally none, although in old materials an evidence of natural pedogenesis can be observed, such a clay translocation. Original profile development may still be present in contaminated natural soils.

RESULTS AND THEIR DISCUSSION

Object of soil classification

In the object classified in the MSCS 2000 is a pedon, or polypedon as three-dimensional pedosphere cut characterized by soil properties, i.e. soil profile with horizons or layers sequences is the central concept of classification (also as anthropogenic soil body). Anthrozem are soils with dominating Anthrozemic Ad-horizon without other diagnostic horizons or with their slight indication. However in the MSCS 2000 it cannot include subaqueous soils, and also bodies under geomembrane or technic hard rock like in WRB 2006. It means the object of soil classification in MSCS 2000 is soil body to be developing under natural or anthropic conditions.

The object classified in the WRB 2006: Technosols are soils with strong human influence, soils containing many artifacts. The WRB has taken the more comprehensive approach to name any object forming part of the epidermis of the earth WRB (Nachtergaele, 2005). Object in the WRB is defined

as any material within 2 m from the Earth's surface that is in contact with the atmosphere, with the exclusion of living organisms, areas with continuous ice not covered by other material, and water bodies deeper the 2 m. The definition includes continuous rock, paved urban soils, soils of industrial areas, cave soils as well as subaqueous soils.

This approach has number advantages notably that it allows tackling environmental problems in a systematic and holistic way and avoids sterile discussions on a universally agreed definition of soil and its required thickness and stability. On the other side this approach do not respect classification of soil body alone and broaden their definition more on mapping units than on soil body.

Correlation of anthropogenic soils groups

It is needed to note that diagnostics, definition and classification of cultivated soils (included into the group of anthropogenic soils) are quite well correlated soil types in soil classification systems of many countries; and also with Anthrosols of WRB 2006. Cultivated horizons are defined in both systems; their differentiation is made according to various manner of soil cultivation. We can find many analogue soil types among many world and national soil systems, e.g. comparable soil units for soils deeply cultivated in gardens are: Aric Anthrosol (FAO), Hortisols (Germany), Anthroposol transformed, hortic (France) and Hortic Kultizems, (Slovakia) and Hortic Anthrosols (WRB 2006). The new proposal is the former group of anthropogenic soils in the MSCS 2000 to be divided into two groups: Kultizems and Anthrozems. This approach can be considered in the new revision version of the MSCS 2000. It may distinguish completely heterogeneous soil groups although of common anthropic genesis, but affecting by different anhropic actions.

Correlation of Anthrozems and Technosols

Anthrozem in MSCS 2000 is perceived like man-made soil body with following Anthrozemic diagnostic Ad-horizon, prevailingly of initial stage developed from anthropogenic substrata (removed, replaced material «ex situ»). This is the central classification concept and the most important feature for their diagnostics. Classification of anthropogenic substrata according to MSCS 2000 is in the Table 1; also presence of artifacts is regarded but not quantified. Soils are very young by their age, so-called substrate soils having Ad-C, or Ad-C-D profiles. There is very often recognizable a soil heterogeneity both at horizontal and vertical level, stratification of soil horizons or soil layers, and the presence of buried and relict horizons or their remnants (high pedo-diversity). Initial pedogenetic process, is running in soil profile where the initial top horizon often keeps inherited properties of anthropogenic substrata.

Table 1

Classification of anthropogenic (transported) substrata according to the Morphogenetic Soil Classification system of Slovakia (2000)

Substrata of natural provenance:	**(ap)**
Sands	(ap1)
Loamy earth	(ap2)
Clays	(ap3)
Gravels	(ap4)
Loamy gravel-sands	(ap5)
Stony-boulder material	(ap6)
Mixed loamy-gravel-sands with stony material	(ap7)
Peat and humolite material	(ap8)
Substrata of natural-technogenic provenance:	**(az)**
Waste of mining industry	(az1)
Waste of metallurgic industry	(az2)
Mixed technologic-recultivated materials	(az3)
Substrata of technogenic provenance:	**(at)**
Building refused material (with components of bricks, concrete, plastic material, mortar, cement, iron, glass, asphalt, etc.)	(at1)
Ashes (products of black and brown coal processing, inflammable refuse)	(at2)
Slug and cinder (products of iron and coloured metals processing)	(at3)
Dumping waste (with components of domestic and municipal refuse)	(at4)
Sludge bogs (sludge waste)	(at5)
Industrial waste (refused products of chemical, metallurgic, plastic, wood-processing, dye-processing and gas industry)	(at6)
Bio-technologic refuse (composted organic refuse)	(at7)

Technosols are soils having 20 percent or more (by volume) of artefacts in the upper 100 cm from the soil surface or to continuous rock a cemented or indurated layer; or a continuous, very slowly permeable to impermeable constructed geomembrane of any thickness starting within 100 cm of the soil surface; or technic hard rock starting within 5 cm of the soil surface and covering 95 percent of horizontal soil extent.

The main classification criterion for Technosols diagnostics is the above mentioned preconditions, mainly more than 20 % of artefacts of solid or liquid phase. This precondition is quite well correlated with substrata of MSCS 2000: of natural-technogenic provenance and technogenic provenance, although the percentage of artifacts is not quantified. So there is a need of more detailed quantification of MSCS 2000. Anthrozemic Ad-horizon (developed from anthropogenic substrata) is not considered in the WRB 2006 (Table 2).

Table 2

Correlation of diagnostic properties of Anthrozems with those in Technosols

Diagnostic properties of Anthrozems	Approximated properties in Technosols
Anthrozemic Ad-horizon (developed from anthropogenic substrate) characterized by:	Not considered
>1 cm thickness	Not considered
Organic carbon content > 0.3 %	Not considered
Presence of arfetacts	Yes: precondition: > 20 % (by volume, by weighted average) artifacts in the upper 100 cm from the soil surface
Anthropogenic parent (removed) material:	Yes
a) by natural origin	No: precondition not for Technosol
b) by natural-technogenic origin	Yes: precondition like for Technosol
c) by technogenic origin	Yes: precondition like for Technosol
Not considered	Constructed geomembrane of any thickness staring within 100 cm of the soil surface
Not considered	Technic hard rock staring within 5 cm of the soil surface and covering 95 percent or more of the horizontal extent of the soil.

Correlation of both soil types is a little complicated due to different classification principles: MSCS 2000 has seven-level category system (soil group – soil type – soil subtype – variety – form – texture – parent material.) in contrary to WRB 2006 with two-level categories: reference soil group – soil type (represented by prefix and suffix qualifiers and specifiers). Nevertheless a comparison of both soil types is feasible. The first classification criteria can correspond according to parent material: Anthrozems to be developed from natural-technogenic or technogenic substrata can be classified as Technosol. Anthrozem to be developed from natural but transported material can be classified like Transportic Regosol, or Arenosol, i.e. there is dominating natural process (Table 3).

Table 3

Anthrozems in relation to WRB 2006 classification

Anthrozems to be classified from parent material:	Classification in the WRB 2006
a) of natural origin (without artefacts)	Like Transportic Regosol, or Arenosol
b) of natural-technogenic origin (with presence of artefacts)	Like Technosol (precondition of more than 20 % artefacts in the upper 100 cm from the soil surface)
c) of technogenic origin (with presence of artefacts)	Like Technosol (precondition of more than 20 % artefacts in the upper 100 cm from the soil surface)

Correlation of soil units of both systems (Anthrozems in the MSCS 2000 and Technosols in the WRB 2006) is involved in the Table 4.

Correlation of the MSCS 2000 and WRB 2006 brought several interesting results. In the MSCS 2000 the classification object is soil body to be developing under natural or anthropic conditions. In the WRB 2006 the object of classification is understood wider: in sense of Earth's epidermis which can include continuous rock, paved urban soils, soils of industrial areas, etc. In this situation we suppose that in many classification systems in the world the dilemma of soil body versus Earth's epidermis will be discussed in future.

Reference soil group in WRB 2006 represents the unique soil group characterized by specific soil properties differing from others. Therefore also in a new revising proposal of MSCS 2000 it will be appropriate to divide group of anthropogenic soils into two groups of 1) Kultizems and 2) Anthrozems due to their different condition of anthropic actions.

Table 4

Correlation of soil units of Anthrozems with those in Technosols

Anthrozem in MSCS 2000	Technosol in the WRB 2006
Soil type: Anthrozem modal (with Ad-horizon ≥10 cm)	*Reference soil group:* Technosol or Regosol (Arenosol) supplemented by prefixes or suffixes
Anthrozem initial (with Adi-horizon 1-10 cm)	Technosol or Regosol (Arenosol) supplemented by prefixes (Leptic, etc.) or suffixes (Skeletic, Arenic, Siltic, Clayic, etc.)
Anthrozem recultivated (with Adr-horizon)	Technosol or Regosol (Arenosol) supplemented by prefixes (Mollic, or Umbric, etc.) or suffix (Humic, etc.)
Anthrozem recovered (with upper organic layer ≥35 cm)	Technosol or Regosol (Arenosol) supplemented by prefixes (Folic, Histic) or other suffixes
Varieties: Acid Calcareous Alkaline Contaminated	*Prefixes or suffixes:* Suffix Dystric (not considered in qualifiers) Suffix Calcaric (not considered in qualifiers) Suffix Alcalic (not considered in qualifiers) Suffix Toxic
Forms: Urbic Garbic Spolic	*Prefixes or suffixes:* Prefix Urbic Prefix Garbic Prefix Spolic

Note: Prefixes Ekranic, Linic, Cryic, Alic, Acric and Lixic are not considered in the MSCS 2000, as well as Oxyaquic and Novic suffixes

Correlation of diagnostic properties of Anthrozems with those of Technosols can result in two similar and matched diagnostics: presence of artefacts in soil profile (in the MSCS 2000 not quantified) and anthropogenic parent material. Both diagnostic materials can be regarded as the central concept of Anthrozems and Technosols classifications. Ad-horizon (initial top horizon which inheriting properties of anthropogenic substrata) is not considered in the WRB 2006. Also constructed geomembrane and technic rock are not included in the MSCS 2000 as definition of soil body does not permit it. To find suitable solution for this is the task for future.

Correlation of both soil types shows some differences in their classification. Technosol can be classified only like Anthrozem developed from natural-technogenic and technogenic material at precondition of more than 20 % artefacts in the upper 100 cm from the soil surface. Soils developed from natural transported material (MSCS 2000) are classified as Transportic Regosol or Arenosol.

CONCLUSION

We have correlated diagnostic properties and classification units of Technosols involved in the latest issue of WRB 2006 and Anthrozems in the MSCS 2000. The main reason to do it was an endeavour to highlight the essential differences in soil properties and find the main classification criteria of these soils. The main purpose was refinement the MSCS 2000 especially classification of Anthrozems. Results of correlation indicate some discrepancies in perceiving of classified object. Diagnostic criteria are comparable in artifacts presence and anthropogenic material. However soil properties in the MSCS 2000 have to be more qualified and refined. Soil units of the MSCS 2000 can be matched with those in the WRB 2006. Finely we have point out a need to revise the existing classification system of anthropogenic soils in Slovakia in order to implement new ideas of WRB 2006.

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