Pedometrics application for correlation of Hungarian soil types with WRB

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Abstract
The development of the recent European and global initiatives resulted in an increasing demand for harmonized digital soil information. The correlation of different national classification systems has an increased importance in the development of European and global databases.
Since 1998, the World Reference Base for Soil Resources (WRB) is the global correlation scheme for soil classification and international communication.

Minasny *et al*. (2009) introduced an attempt to visualize the taxonomic distances between the WRB Reference Soil Groups (RSGs). The modified method of Minasny's approach may provide a new tool to correlate different soil classification systems based on the taxonomic relationships of the classification units. A study was conducted to test new correlation possibilities with WRB on the example of the Brown forest soils (BFS) main type of the Hungarian Soil Classification System (HSCS) where the lack of definitions and limits often causes difficulties in classification and correlation.
In this study, we attempt to determine the taxonomic distance between the different types of BFS of Hungary and related WRB RSGs based on dominant identifiers.

Key words
Correlation, dominant identifiers, taxonomic relationship, World Reference Base for Soil Resources.

Introduction
The recognized need for harmonized soil information resulted in EU and global projects such as e-SOTER (Regional pilot platform as EU contribution to a Global Soil Observing System). In order to achieve harmonized databases, objective correlation methodologies are required.

Based on the different approaches of national soil classification systems, or varying criteria of similar soil units, this task is often complicated. The initiation of a new, harmonized field survey campaign seems unrealistic in the near future, thus the only solution is the harmonization of existing data, which requires a common system and classification of soil variables (Dobos 2006).

To solve this problem, a correlation system had to be created. Based on the Legend and the Revised Legend of the Soil Map of the World of the Food and Agriculture Organization of the United Nations (FAO), a Working Group of the International Soil Science Society (ISSS, now International Union of Soil Sciences - IUSS) established a framework through which existing soil classification systems could be correlated and harmonized. This framework was published in 1998 as the first edition of the World Reference Base for Soil Resources (WRB) was published. The same year, the ISSS endorsed WRB as the global correlation scheme for soil classification and international communication, and the European Commission also selected it as the correlation scheme for harmonized soil maps and databases for Europe. These decisions provided an opportunity to use a common and global language in soil science and also provided a system to supply harmonized soil information. Most correlation studies are based on morphological and analytical data of selected soil profiles or general descriptions of the soil units.

The "revisited" numerical classification can be a new tool for correlating different classification systems. The idea of numerical taxonomy mainly comes from botanists (Adanson 1763), and the methodology came into reality in the 1950s thanks to digital computers. The first application for soil classification was made by Hole and Hironaka (1960), later Bidwell and Hole (1964a) calculated numerical indices of similarity for some US soils. In the early stages of numerical classification many studies were completed for soil classification (Bidwell *et al.* 1964b, Sarkar *et al.* 1966, McBratney *et al.* 2000), but mainly based on local data with limited scope. National and international experiments were not done yet (McBratney *et al.* 2009). The increasing demand for harmonized digital soil information resulted in the claim for new correlation methods.

Minasny *et al.* (2009) introduced an attempt to visualize the taxonomic distances within the WRB Reference Soil Groups (RSGs). The modified method of Minasny's approach may provide a new tool to correlate different soil classification systems based on the taxonomic relationships of the classification units.
A study was conducted to test new correlation possibilities with WRB on the example of the Brown forest soils (BFS) main type of the Hungarian Soil Classification System (HSCS) where the lack of definitions and limits often causes difficulties in classification and correlation.

Materials
The WRB (IUSS Working Group WRB 2006) is based on a diagnostic approach. 32 Reference Soil Groups (RSGs) are defined by a key, based on the presence, sequence or exclusion of diagnostic horizons, properties and/or materials. The lower levels are defined by qualifiers added to the names of the reference soil groups for specific soil characteristics.

The current Hungarian Soil Classification System (HSCS) was developed in the 1960s, based on the genetic principles of Dokuchaev. The central unit is the soil type grouping soils that were believed to have developed under similar soil forming factors and processes. The major soil types are the highest category which groups soils based on climatic, geographical and genetic bases. Subtypes and varieties are distinguished according to the assumed dominance of soil forming processes and observable/measurable morphogenetic properties.
On the highest, *Major Soil Type* level, 9 categories are distinguished: skeletal soils, shallow soils influenced by the parent material, brown forest soils, chernozems, salt affected soils, meadow soils, peat soils, soils of swampy forests, and soils of alluvial and slope sediments.
In the highest extent (24,6%) the brown forest soils cover the territory of Hungary (Figure 1).

Brown forest soils of HSCS
The brown forest soils (BFS) generally formed under forest vegetation and are characterized by dominant downward moisture movement. This main type is a broad category that includes members without or with distinct subsurface horizons, thus the lack of definitions and limits often causes difficulties in classification and correlation. In the BFS main type 7 subtypes are distinguished: Chernozem BFS, Brown earths, Lesivated BFS, Podzolised BFS, Pseudogley BFS, Lamellic BFS, Acidic non podzolised BFS (Micheli *et al.* 2006).

Methods
The approach of Minasny *et al.* (2009) to determine taxonomic distance for WRB soil groups was further improved for correlation purposes.

The taxonomic distance measurement was based on Table 1, which contains the 7 Hungarian BFS classes and the 14 possibly related RSGs. The selection of the RSGs was based on previous correlation attempts (Micheli *et al.* 2006) and field experiences.

Based on the criteria defined in the WRB 2006 key and on the information content of the BFS classification units, dominant identifiers were selected. From all the diagnostic horizons, properties or materials in the key that determine and characterize the selected RSGs, 16 were selected that occur between the environmental conditions of Hungary. This list was completed with 2 more characteristics that are present just at the lower (qualifier) level of WRB, but are important to determine the BFS of the HSCS.

The 18 identifier properties were matched with the 21 soil groups, and were coded 0 when the condition cannot be present, 0.5 when the condition can be present, and 1 when the condition is a criteria for the selected group (Table 1). Compared to Minasny *et al.* (2009), code 0.5 was introduced newly and the definition of code 1 was changed from "likely to be present" to "obligatory to be present", for better characterization of the soil. In case of BFS expert judgment was needed during the coding due to the lack of definitions and quantitative criteria.

Based on the matrix, the distance between the selected WRB and Hungarian BFS groups was calculated:

$$d_{ij} = \sqrt{\left(\mathbf{x}_i - \mathbf{x}_j\right)^{\mathrm{T}}\left(\mathbf{x}_i - \mathbf{x}_j\right)}$$

where d_{ij} is the element of distance matrix D with size $(c \times c)$, c is the number of soil groups. The value of d_{ij} represents the taxonomic distance between soil group *i* and group *j*, and *x* refers to a vector of indicators of the soil identifiers (Minasny *et al.* 2009).

Results and discussion

In Table 1, 21 soil groups (14 RSGs of WRB and 7 BFS units of HSCS) were matched and coded with the selected dominant identifiers.

Table 1. 21 soil groups matched and coded with the selected dominant identifiers

	Podzols	Planosols	Stagnosols	Chernozems	Kastanozems	Phaeozems	Calcisols	Alisols	Luvisols	Lixisols	Umbrisols	Arenosols	Cambisols	Regosols	Chernozem BFS	Brown earths	Lessivated BFS	Podzolised BFS	Pseudogley BFS	Lamellic BFS	Acidic, non-podzolised BFS
Histic, Folic	0,5	0,5	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,5	0,5	0,0	0,0	0,0	0,0	0,0	0,5	0,5
Vertic	0,0	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,5	0,0	0,5	0,0	0,0
Fluvic	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Natric,Sodic	0,0	0,5	0,5	0,5	0,5	0,5	0,5	0,0	0,5	0,0	0,0	0,0	0,5	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Salic	0,0	0,5	0,5	0,5	0,5	0,5	0,5	0,0	0,0	0,0	0,0	0,5	0,5	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Gleyic	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Spodic	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,0	0,0
Abrupt textural change	0,0	1,0	0,0	0,0	0,0	0,5	0,0	0,5	0,5	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0
Stagnic	0,5	0,5	1,0	0,5	0,5	0,5	0,0	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,0	0,0	0,0	0,0	1,0	0,0	0,0
Mollic	0,0	0,5	0,5	1,0	1,0	1,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	1,0	0,5	0,5	0,0	0,0	0,5	0,0
Calcic, Calcaric	0,0	0,5	0,5	1,0	1,0	0,5	1,0	0,0	0,5	0,5	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Umbric	0,5	0,5	0,5	0,0	0,0	0,0	0,0	0,5	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,5	0,5	0,5	0,5	0,5
Arenic	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	1,0	0,0	0,5	0,0	0,5	0,0	0,5	0,0	1,0	0,0
Cambic	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	1,0	0,0	0,5	1,0	0,5	0,5	0,5	0,5	1,0
Argic (high CEC, high base)	0,0	0,5	0,5	0,5	0,5	0,5	0,5	0,0	1,0	0,5	0,0	0,0	0,0	0,0	1,0	0,0	1,0	0,0	1,0	0,5	0,0
Argic (high CEC, low base)	0,0	0,5	0,5	0,0	0,0	0,0	0,0	1,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,0	0,0
Lamellic	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,5	0,5	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0
Dystric	1,0	0,5	0,5	0,0	0,0	0,0	0,0	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,0	0,0	0,0	1,0	0,5	0,5	1,0

Based on Table 1, the taxonomic distances between the selected WRB RSGs and the Hungarian BFS units were calculated. The 3rd and 4th column of Table 2 show the two nearest RSGs correlated with the different BFS units. Our results show good relationship with previous studies on the correlation of the HSCS with WRB (2nd column of Table 2).

Table 2. Hungarian BFS units and their possible correlations in WRB

HBFS Units	Possible correlations based on Micheli *et al.* (2006)	Closest RSGs based on distance matrix	2nd closest RSGs based on distance matrix
Chernozem BFS	Chernozems, Kastanozems, Phaeozems	Phaeozems	Kastanozems
Brown earths	Cambisols	Regosols, Cambisols, Arenosols, Umbrisols	Phaeozems, Lixisols
Lesivated BFS	Luvisols	Phaeozems, Luvisols	Calcicols
Podzolised BFS	Luvisols, Umbrisols	Podzols	Alisols
Pseudogley BFS	Luvisols	Luvisols	Stagnosols, Umbrisols
Lamellic BFS	Luvisols	Arenosols	Lixisols, Umbrisols
Acidic, non-podzolised BFS	Cambisols, Umbrisols	Cambisols	Umbrisols, Regosols, Podzols

The main difference between the previous studies and the new approach was found in case of the Podzolized BFS unit. The accumulation horizon of most Podzolized BFS does not satisfy the criteria of the diagnostic spodic horizon (Micheli *et al.* 2006), so these soils do not correlate with WRB Podzols but with low base saturation Alisols or Umbrisols. The uncertainty of our results is possibly due to the different approach of the two studied classification systems, and the lack of definitions and quantitative criteria in HSCS. We suggest the check of the results with classification experts of the studied area.

CONCLUSIONS

Taxonomic distances between BFS and related WRB soil groups have been established.

The modified approach of Minasny *et al.* (2009) was found suitable for correlation purposes, with the following suggestions:

- The changing of the definition of code 1 and the introduction of code 0.5 was found more appropriate to determine taxonomic distance between soil groups.
- The correlation of diagnostic and genetic-based soil classification systems is possible with the tool of taxonomic distance measurement, but the selection of related soil groups and the coding against the dominant identifiers need previous studies or expert judgement. For similar reasons we suggest to check the final results also with classification experts of the studied area.
- Based on the reviewed literature and our results we conclude that this paper is only the beginning of our work. In the future we try to give a better understanding of the correlations with more soil types/groups.

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