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Traditional and pedometric approaches to justify the introduction of swelling clay soils as a new soil type in the modernized Hungarian Soil Classification System

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ABSTRACT

Clay and clay loam textured soils that are mainly characterized by smectite dominated mineralogy cover about 25% of the territory of Hungary (Stefanovits and Dombóvári, 1985). Despite their distinctive morphology, special characteristics and widespread coverage, these soils belong to several different taxonomic units in the current genetic based Hungarian Soil Classification System (HSCS), making the differentiation and definition of several units and correlation with international standards difficult.

As part of the ongoing modernization process of the HSCS, detailed documentation of high smectite clay content, shrinking and swelling soils developed on different substrates, topographical positions and geographical areas was carried out in Hungary. The collected data was correlated with the World Reference Base for Soil Resources and the dominant soil forming processes were linked to diagnostic elements. The traditional soil classification methodology was supplemented with the modern pedometric method of centroid based taxonomic distance calculation to evaluate the taxonomic relationship between the Hungarian clay soils and the WRB Reference Soil Groups. Our findings confirmed that the swelling clay soils of Hungary satisfy the morphological and measureable physical and chemical criteria of the WRB Vertisol Reference Soil Group. The centroid based taxonomic distance calculations were successfully applied for objective expression of similarities and differences between the examined soil types. The studied profiles and the applied methods justify the introduction of swelling clay soils to the highest level of the modernized Hungarian Classification System. The applied methodology can be a useful tool in evaluation, improvement or development of other soil classification systems.

1. Introduction

Shrinking and swelling clay soils with deep, wide cracks when dry, while sticky and plastic when moist have been well known by farmers since the first agricultural systems were developed, and are distinguished from other soil types because of their tillage problems (Wilding and Puentes, 1988; Eswaran et al., 1999; Buol et al., 2003).

Due to their widespread geographical coverage, and unique morphological, physical, chemical and management properties, many modern international soil classification systems, like the US Soil Taxonomy (Soil Survey Staff, 1999), the IUSS accepted international correlation system, the World Reference Base for Soil Resources (IUSS Working Group WRB, 2007) and most national soil classification systems (i.e. Russian, French, German, Czech, Slovak, Romanian, Chinese, Australian and South African), define the swelling clay soils at the highest level of the classification, as Vertisols.

Descriptions of the unique properties and significant extent of this type of soils can be found in the Hungarian soil science literature since the late 1800s, mentioned as “meadow clays” and “black erubase” soils (Szabó and Molnár, 1866; Treitz, 1893; Timkó, 1912; Ballenegger, 1921; Csiki, 1936; Kreybig, 1944). The current Hungarian Soil Classification System (HSCS) was developed between the 1950s and 1960s, based on the genetic principles of Dokuchaev. The system is rather descriptive; the taxonomic units are differentiated based on the recognition of sets of soil forming processes using a soil geographic approach and limited laboratory data. The system consists of 4 levels; the central unit is the “soil type” grouping soils that were believed to have developed under similar soil forming processes. At the highest “major soil type” level, climatic and geographic factors are considered, while for further characterization of the soil types “subtypes” and “varieties” are defined at the 3rd and 4th levels based on the dominance of soil forming processes and observable or measurable morphogenetic properties.

Although Máté (1955) suggested the differentiation of shrinking and swelling meadow soils at the second, “soil type” level of the classification during its development, this approach was de-emphasized, and in the current HSCS these soils belong to several different soil taxonomic units. The high clay, mostly smectitic soils are included in the meadow-, salt affected-, parent material influenced-, and alluvial main soil types of the HSCS, often grouped together with significantly

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different soils. The indication of the high clay content is therefore not possible even at the lower, detailed levels of the system.

Re-discovery of the shrinking and swelling clay soils in Hungary started again during the 2000s, during the modernization of the current, genetic based HSCS. The modernization process of HSCS is based on a diagnostic approach, and includes the application of numerical methods (Láng et al., 2010; Fuchs et al., 2011; Láng, 2013; Láng et al., 2013), the development of a computer assisted classification key (Láng, 2013), and correlation with international systems (Michéli et al., 2014a, 2014b).

The physical, chemical and morphological characteristics, as well as the classification and correlation problems of swelling clay soils are extensively documented (Fuchs et al., 2005; Michéli et al., 2006; Fuchs et al., 2007; Fuchs et al., 2008; Fuchs and Michéli, 2010), and the novel method of taxonomic distance calculation was applied to elaborate suggestions for the introduction of a new soil type in the modernized, diagnostic based Hungarian Soil Classification System.

2. Materials

Based on a detailed review of the Hungarian Soil Classification System, soil mapping history related literature, and the field experiences of the authors, nineteen reference profiles with shrinking and swelling properties were selected (Table 1) to represent different Hungarian soil types (according to the current system), a variety of parent materials, different topographic positions and diverse geographical distribution in Hungary (Fig. 1).

3. Methods

3.1. Site and soil profile description

Site descriptions of the reference profiles were performed in soil pits according to the international standards published as "guidelines for soil description" by FAO (2006). Disturbed and undisturbed soil samples were collected and analyzed from 65 genetic horizons of the reference profiles for further characterization.

3.2. Laboratory methods

Color of the samples was identified by the Munsell color scale in dry and wet state. Soil pH (pH [H_2O]; pH [KCl]) was determined by the potentiometric method (1:2.5 dilution), $CaCO_3$ content was measured by the Scheibler gas-volumetric method (Buzás, 1988). Soil organic matter (SOM) content was measured according to the Walkley–Black method (Van Reeuwijk, 1995), cation exchange capacity (CEC) and exchangeable basic cations (S value) were determined based on the Mehlich-method (Mehlich, 1953). Base saturation was calculated as the following: Sum of exchangeable basic cations (S) / CEC ∗ 100. Electric conductivity (EC) was measured in a saturated soil paste, and salt content was calculated from the EC values according to Buzás (1988).

The bulk density was determined on undisturbed core samples (Buzás, 1993), particle size analysis was conducted by the pipette method (Buzás, 1993). Coefficient of Linear Extensibility (COLE) was determined by the rod method (Schafer and Singer, 1976).

Table 1
Description of the Hungarian sample locations.

Profile	Location	Coordinates	Parent material	Landform topography	Slope
1.	Szirák 1a	N 47°49′47.41″ E 19°33′35.35″	Reworked, mixed loess and weathered volcanic deposit	Toe slope	2–5°
2.	Szirák 1b	N 47°49′47.41″ E 19°33′35.35″	Reworked, mixed loess and weathered volcanic deposit	Toe slope	2–5°
3.	Szirák 2	N 47°49′32.33″ E 19°33′33.62″	Reworked, mixed loess and weathered volcanic deposit	Upper slope	5–10°
4.	Kisnána	N 47°50′57.84″ E 20° 9′49.27″	Reworked, weathered volcanic deposit	Toe slope	2–5°
5.	Gyöngyös	N 47°44′14.16″ E 19°52′38.90″	Reworked, weathered volcanic deposit	Plain	<2°
6.	Atkár	N 47°42′23.17″ E 19°52′48.13″	Reworked, weathered volcanic deposit	Toe slope	2–5°
7.	Apc	N 47°48′15.13″ E 19°40′20.10″	Reworked Pleistocene slope deposit	Plain	<2°
8.	Vajdácska	N 48°18′49.91″ E 21°38′26.44″	Alluvium	Floodplain	<2°
9.	Dorkó Tanya	N 48°14′02.33″ E 21°38′55.25″	Alluvium	Floodplain	<2°
10.	Bodroghalom	N 48°18′17.21″ E 21°41′19.44″	Alluvium	Floodplain	<2°
11.	Nagyrozvágy	N 48°20′25.71″ E 21°53′35.19″	Alluvium	Floodplain	<2°
12.	Szenna-tanya	N 48°18′51.45″ E 21°52′46.87″	Alluvium	Floodplain	<2°
13.	Kisújszállás	N 47°14′8.31″ E 20°44′8.68″	Infusion loess	Plain	<2°
14.	Törökszentmiklós	N 47°11′5.51″ E 20°27′55.05″	Alluvium	Plain	<2°
15.	Karcag	N 47°16′47.31″ E 20°53′12.66″	Infusion loess	Plain	<2°
16.	Tiszasas	N 46°48′36.00″ E 20°05′24.00″	Alluvium	Floodplain	<2°
17.	Cibakháza	N 46°57′48.96″ E 20°12′26.34″	Alluvium	Floodplain	<2°
18.	Kötegyán	N 46°42′22.00″ E 21°27′13.00″	Alluvium	Floodplain	<2°
19.	Tiszabura	N 47°28′38.00″ E 20°32′00.00″	Alluvium	Floodplain	<2°