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Approximation of WRB reference group with reapplication of archive soil databases

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Abstract: In our study we tested the existing and free accessible soil databases covering a smaller geographical region surveyed and classified according to the Hungarian classification in order to approximate the WRB soil reference groups (RSG). We tested the results and applicability of approximation for the RSG with three different methods on 12 soil profiles. First, RSGs were assigned to Hungarian soil taxa based on results of previous correlation studies, second a freely accessible online database of ISRIC was applied furthermore, and an automated reclassification developed and programmed by us was used, which takes the original soil data as input.

Keywords: soil classification, Solonetz, Vertisol, WRB correlation, WRB algorithmization

1. Introduction

As a result of the soil survey works during the past 100 years in Hungary, there are enormous amount of soil data available for meta-analyses. However, due to their different approaches of soil profile description and laboratory methods it is often difficult to imply them for present-day application in researches with novel approaches. Furthermore, because of the limited options and financial resources the requirement for reuse, reclassification and harmonization of these data with later databases is constantly increasing [1]. Several difficulties emerge at this process since these data are based on different methodology and classification system.

Currently the most commonly used soil classification system in Europe is based on the diagnostic approach of World Reference Base for Soil Resources (WRB). It provides well-defined terminology and quantifiable conditions [2]. During the recent years, numerous results were published regarding the mapping of soil databases converted from different sources into WRB [3-10] and the classification of soils with simplified automated algorithms [11].

Láng et al. (2010, 2013) used the taxonomical distance based comparison to perform numerically controlled harmonization of the Hungarian soil classification with the WRB. In their study they investigated the correlation possibilities between the national and the WRB classification in case of brown forest soils (cca. Luvisols, according WRB), using the method for classification purposes for the first time. Based on their results the numeric comparison of the Hungarian soil types to the similar units of WRB became possible [12-13].

The differences and connections between WRB and the Hungarian soil classification were first summarized by Michéli et al. (2006) and Krasilnikov et al. (2009) who also established correlation keys which are primarily based on field experiences and the definitions of the classification units [14].

This study investigates data of soil profiles from an area which was previously mapped and classified based on the Hungarian classification system in order to identify whether it is possible to classify the soil profiles characterized by the archive data according to WRB, and if it is, to define the degree of accuracy. The comparison were used to answer the question if provided we can only acquire the data recorded according to the different methodology and taxonomy, whether the (unambiguously inaccurate and in some cases impossible) reclassification using the data ill-suited to WRB could provide more accurate identification of RSGs than the automatic assigning based on the system-level correlation, or the acceptance of the RSG predicted by the ISRIC database. Since data about taxonomical status of soils assigned properly to WRB in field are available in low spatial density, approximation could be useful in WRB soil mapping and reapplication of archive data as well.

Study area

The investigated profiles are located on the Hortobágy, Dél-Hajdúság and Nagy-Sárrét regions in Eastern Hungary (Fig. 1). The Hortobágy is an abandoned alluvial plain. It is the largest continuous area with alkaline soils in the continent. Approximately 3/4 of the area is covered by alkaline and in deeper soil horizons also salt affected soils. As a consequence of shallow alkaline groundwater, diverse alkaline soil complexes were formed on the silty loess deposits with characteristic mosaic spatial pattern [15].

Dél-Hajdúság is a fossil alluvial plain covered by silty loess. In lower topographic position alkaline meadow chernozem soils can be found with significant clay content which are used predominantly as croplands, but in smaller extent also pastures or forests. In higher elevations more fertile typical carbonatic chernozem soils are dominant. Alkaline and salt affected soils are just in subordinate extent in this landscape, which has great importance from agricultural point of view [16].

Nagy-Sárrét is a recent alluvial plain interspersed with alkaline lands and flood-free areas. Part of it has basin-like characteristics, where in the deeper, artificially drained areas dominantly croplands and in small fragments natural grassland vegetation can be found. All soils of the landscape have been developed under influence of shallow groundwater and partially of temporary surface water cover, which is reflecting in topsoil, but more frequently in the subsoil properties. As result of anthropogenic activities these soils are mostly artificially drained which is expressed in the lowering of groundwater level, and retreat of surface water cover [17].

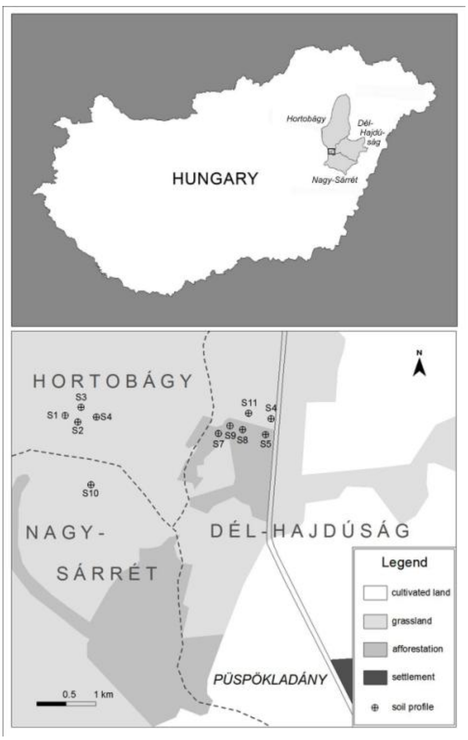

Figure 1:. Location of the study area and the sampling sites in Hungary

2. Materials and Methods

Twelve soil profiles (S1-S12), 1 on the Nagy-Sárrét, 4 on the Hortobágy, and 7 on the Dél-Hajdúság were investigated (Fig. 1). The profiles represents the spatial variability of soils within the three neighbouring region [18]. The preparation, analysis and classification according Hungarian taxonomy of the profiles took place between 1999 and 2002. To compare the results and applicability, three methods for approximation of WRB RSGs were used (Table 1.): 1 assigning the profiles to WRB according the correlation databases between WRB and Hungarian classification's soil taxa, 2 prediction of RSGs based on ISRIC database, 3 results of automatized WRB classification, and the prediction of RSGs. In the first case, we assign to the profiles two or more RSGs were given as possible equivalents according to the correlation table (Michéli et al. 2006) [11]. In the second case, we used the coordinates of profiles in order to predicting the RSG using the ISRIC web services [19-20]. These methods we used to associated the profiles with RSGs and given the probabilities that the database stored in each location. The third case, we carried out the reclassification based on the available data from the soil profiles with automated algorithms which were designed in accordance with the WRB diagnostics.

Table 1 : Overview of the input and output data of the three applied methods for approximation of WRB RSG

Approximation method	Input data	Output data
System level correlation between Hungarian and WRB soil taxa	Hungarian soil type	WRB RSG(s) one or more
Prediction of RSGs based on ISRIC database	Coordinates of the location	WRB RSG(s), several each with probability (%) of occurrence
Automatized reclassification according WRB based algorithms	Soil horizon data from profiles	WRB RSG, one only in case it fits entirely

Possibilities and uncertainties of automatized classification

The possibilities for reclassification of soil data acquired from different sources are limited for a number of reasons. Basically missing data or the sampling method can be the reason, why a given soil profile cannot be classified and assessed with an adequate degree. The automatable method suggested by Eberhardt and Waltner (2010) is different from the previous ones, which is primarily correlation and harmonization of existing soil taxa [5]. The essence of the suggested method is using the original soil survey data to identify the WRB units instead of harmonizing each national classification unit. This requires to design the necessary algorithms separately for every database applying different methodology [11]. But this is rather time consuming, and errors occurring due to the different methods can be corrected only to a limited degree. Nevertheless, after the initial setup of the system practically unlimited amount of soil unit can be classified automatically, therefore it makes possible the process of large databases.

Automatization of classification process

The specification is a development of a plug-in, which is able to classify soils based on the archive data accordance with the WRB. As a preparatory step, our soil data need to be integrated into a processable data structure [21]. Therefore, it is advisable to store the data in relational data tables so that the later processes will be automatized more easily [22]. The first table stores field and laboratory results and further computed data, such as diagnostic levels, attributes, soil materials [23]. The second table records the geographical location of the soil profiles and the result of the classification.

The next phase of the work is the algorithmization of the level verifying, attribute calculating and the main groups specifying components. Since the WRB classification system has fixed criteria and in most cases the archive data do not follow the structure of the idealized system, the method of process is also has to be taken into account.

Decision process of soil RSG

Since the strongly heavy textured soils with high clay content usually form a separate WRB RSG, which directly follows the Solonetz soils in the WRB (2014) system, we assumed that some of them belong to either into the Solonetz or into the Vertisol reference groups based on the available data, references, soil maps and the topographic characteristics of the profiles. In order to reach this conclusion, the possibility of belong to one of the previous five groups had to be excluded (Fig. 2).

The classification as ***Histosol*** group could be excluded, since our profiles does not have organic soil material (>20% C_{org}):

1. at least 10 cm thick, if it starts at the surface and the soil climate is cryic or pergelic, or the underneath soil level is coherent rock, technical solid material or rough debris the cracks of which are filled with organic material, or
2. at least 60 cm thick for 100 cm from the surface, if it starts within 40 cm from the surface and at least 75% of its volume is made up of fibrous peat moss, or
3. at least 40 cm thick for 100 cm from the surface, if it starts within 40 cm from the surface, if it is made up of other material.

The classification can be keyed out at ***Anthrosols*** if the soil does not have a horizon of ≥50 cm thickness which is ploughed, cultivated or changed due to irrigation (hortic, irragric, terric).

The classification keys out at ***Technosols*** if in the top 100 cm layer of the soil the amount of artefacts does not reach 20% by volume or there is no technic hard material or artificially established impermeable geomembrane. Since the examined databases are originated from cultivated or pasture sites, this RSG can be excluded in case of all the investigated profiles.

Cryosols can be excluded in the examined geographical region due to the different soil climate (they do not have cryic horizon), because this RSG cannot be found under the Hungarian climate conditions.

The classification as ***Leptosol*** can be excluded if in the soil:

1. there are no continuous hard rock or technic hard material within 25 cm starting from the surface, or
2. within 75 cm starting from the surface, or if the soil is shallower, down to the surface of the continuous hard rock or technic hard material the fine earth part makes up ≥20% by volume of the entire soil.
3. The parent materials of the study area are unconsolidated sediments, where rough debris or technical solid material can be found only under urbanized conditions due to anthropogenic influence. In this case, however, the soils could be keyed out among Technosols, therefore this RSG could be excluded as well based on the land-use characteristics of the investigated area.

The soil can be classified as ***Solonetz*** if it has a natric horizon within 100 cm starting from the surface, and cannot be classified into any of the previous RSGs. If this condition meets the investigated profile keys out into Solonetz. The next step of process is identification of natric horizon if it presents.

The soil can be classified as ***Vertisol***, if

1. it has a vertic horizon starting within 100 cm from the surface, and
2. if the vertic horizon does not start at the surface, the clay content is ≥30% throughout between the surface and the vertic horizon,
3. the surface is articulated by seasonally opening-closing shrink-swell cracks.

Therefore, in order to decide whether the soil belongs to the Vertisol not only the proving of the vertic horizon was necessary, but the clay content above the vertic horizon (if present) and the presence of cracks within the horizon should also be checked. If based on the established criteria the investigated profile cannot be assigned to any of these RSG-s, the RSG of the profile will be considered as unknown.

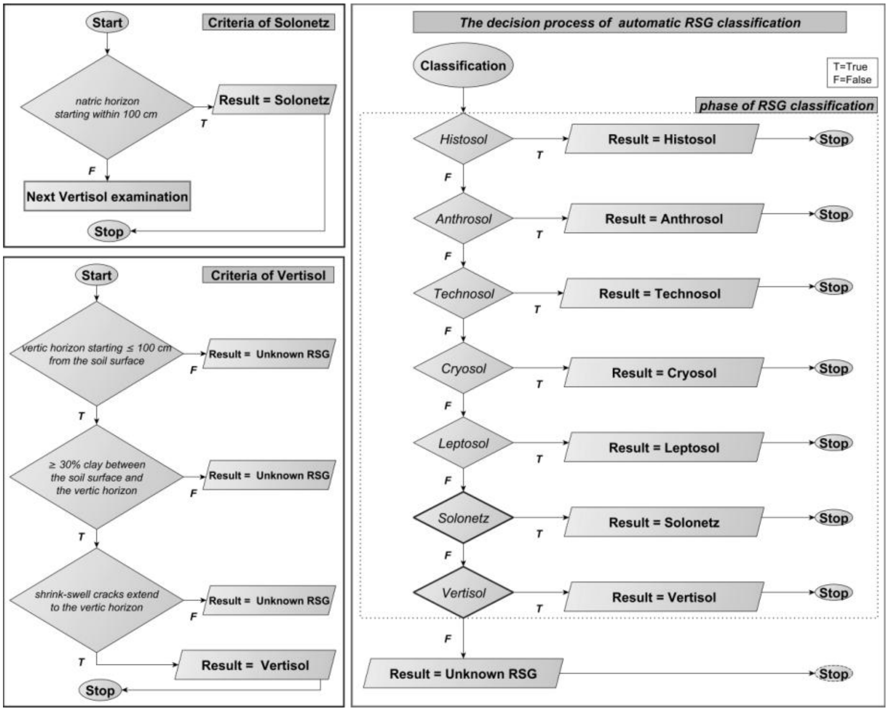

Figure 2:. The process of automatic soil classification.

3. Results and discussions

The profiles were classified as meadow solonetz (S1, S2, S3, S4, S10, S11, and S12), typic meadow soil (S5, S9), meadow chernozem (S7) and solonetzic meadow soil (S6, S8) categories according to the Hungarian classification system (Table 2.). Due to the correlation project, the result of the classification could be compared to the results published by Michéli et al (2006). The following RSGs were established for the types identified by us according to the Hungarian taxonomy: meadow solonetz –Solonetz, Vertisol; typic meadow soil – Phaeozem, Chernozem; Vertisol; meadow chernozem – Chernozem and solonetzic meadow soil – Vertisol, Cambisol.

The estimation of RSG based on the ISRIC database provides more information, as far the probability of RSGs associated with a given location is also predicted, nevertheless these data can be considered only as an approximation as well.

The last column of Table 2 includes the RSG as results of the automatized classification carried out by the software developed by us. Five profiles were classified as Solonetz, 4 were classified as Vertisol and 3 were considered as

RSG unknown. In case of profiles which were considered to belonging in unknown RSG, the available data were not sufficient for the automated classification, or the profile could not even provisionally be classified into any of the RSGs, because the classification requirements were not met. In the first case the missing ESP (Exchangeable Sodium Percentage) values of S1 and S2 excluded them being classified as Solonetz. In the case of S7 either the available data were not sufficient, or it is placed behind the Vertisol in the WRB system, and in this study we does not dealt with the classification of those RSGs.

Table 2 : Soil type (Hungarian classification) and identification of RSGs based on system level correlation (Michéli et al 2006), soil map data based approach (ISRIC) and soil profile data based automatized reclassification

Profile ID	Hungarian Soil Type	Results of Michéli et al. (2006) correlation	RSG according to ISRIC	RSG according to automatic classification
S1	meadow solonetz	Solonetz/Vertisol	Solonchak (18%), Solonetz (14%), Vertisol (12%)	Unknown
S2	meadow solonetz	Solonetz/Vertisol	Solonchak (18%), Solonetz (14%), Vertisol (12%)	Unknown
S3	meadow solonetz	Solonetz/Vertisol	Solonchak (18%), Solonetz (14%), Vertisol (12%)	Solonetz
S4	meadow solonetz	Solonetz/Vertisol	Solonchak (18%), Solonetz (14%), Vertisol (12%)	Solonetz
S5	typic meadow soil	Phaeozem/Chernozem/Vertisol	Vertisol (17%), Solonchak (13%), Solonetz (12%)	Vertisol
S6	solonetzic meadow soil	Vertisol/ Cambisol	Vertisol (17%), Solonchak (13%), Solonetz (12%)	Vertisol
S7	meadow chernozem	Chernozem	Solonetz (13%), Solonchak (13%), Vertisol (10%)	Unknown
S8	solonetzic meadow soil	Vertisol/Cambisol	Vertisol (17%), Solonchak (13%), Solonetz (12%)	Vertisol
S9	typic meadow soil	Phaeozem/Chernozem/Vertisol	Solonchak (19%), Solonetz (17%), Vertisol (11%)	Vertisol
S10	meadow solonetz	Solonetz/Vertisol	Solonchak (19%), Solonetz (14%), Vertisol (9%)	Solonetz
S11	meadow solonetz	Solonetz/Vertisol	Vertisol (17%), Solonchak (13%), Solonetz (12%)	Solonetz
S12	meadow solonetz	Solonetz/Vertisol	*Unknown coordiantes*	Solonetz

Based on the results it can be seen that in some cases the archive soil data sources do not contain sufficient information to identify unambiguously the diagnostic horizons of the profiles according to WRB. In accordance with the methodology of WRB, this excludes the classification of soil profiles according to WRB, since it requires the information about the present diagnostic horizons to assign or exclude any RSGs, therefore the result of the automated classification led to unknown result. The vertical position of identified diagnostic horizons in the studied 12 profiles based on the available data, are represented in Figure 3. Because of the lack of data, not only the positive identification of certain horizons are difficult, but also frequently the exclusion of them (Table 3.).

In some cases the specific data types were not available, and there were other soil data (categorical or derived data) based on the given feature (e.g. surface cover, soil moisture household, and soil climate type) could be inferred (however not in a numeric way). For example the presence of shrink swell cracks is a diagnostic criteria to identify vertic horizon, but earlier databases does not contain information concerning on that, in exception of mentioning deep, wide cracks at the description of structure. The most frequent problem out of the ones associated with the data was the limited number of data regarding depth. The established database managed some of its data with a topsoil-subsoil distinction, which in a lot of cases makes it more difficult or excludes entirely the possibility of precise examining of the depth criteria according the WRB. Since the data collection and the division of the profiles to horizons were not carried out in accordance with the guidelines of WRB, therefore the indication of diagnostic horizons conforms to the sampled layers, and are not necessarily in accordance with the boundaries of diagnostic horizons which could be observed and identified in the field.

The applied three methods to estimate WRB RSGs lead to different results. In the case of the classification based on types of the Hungarian taxonomy applying the results of former correlation studies there was not possible to assign to just one RSG, but two, or even three RSGs were given as possible equivalents, without estimation of probability. Therefore, the unambiguous reference group identification is not possible in this way. The approximation of RSG using the ISRIC database is more useful, because the probabilities of possible RSG-s were associated to a given profile. The spatial resolution of this database, however, is not adequate to precisely describe the heterogeneity of the area. Based on the coordinates of the investigated profiles the ISRIC database predicted Solonchak and Solonetz RSGs. In addition, in one case RSG prediction was not possible due to missing coordinates. In case of automated data classification five profiles were classified as Solonetz, four as Vertisol and three were keyed out as RSG unknown, or impossible to predict while data missing . The most question in our study – in addition to missing data – was the uncertainity of identification of diagnostic horizons (natric, vertic, calcic, and mollic) based on the archive data. Since the data collections were not carried out in accordance with the guidelines of WRB, the indication of diagnostic horizons conforms to the sampled layers (diagnostic horizons calculated from the layers), which are not definitely in accordance with the boundaries of horizons which can be identified in the field, therefore it can only serve as a basic for the identification. However, regarding the assessment and application of decision making rules of the established RSGs, it should be noted that these only mean a "best approximation" for the studied archive soil data and do not substitute the field data collection, description and classification process according to the detailed WRB methodology.

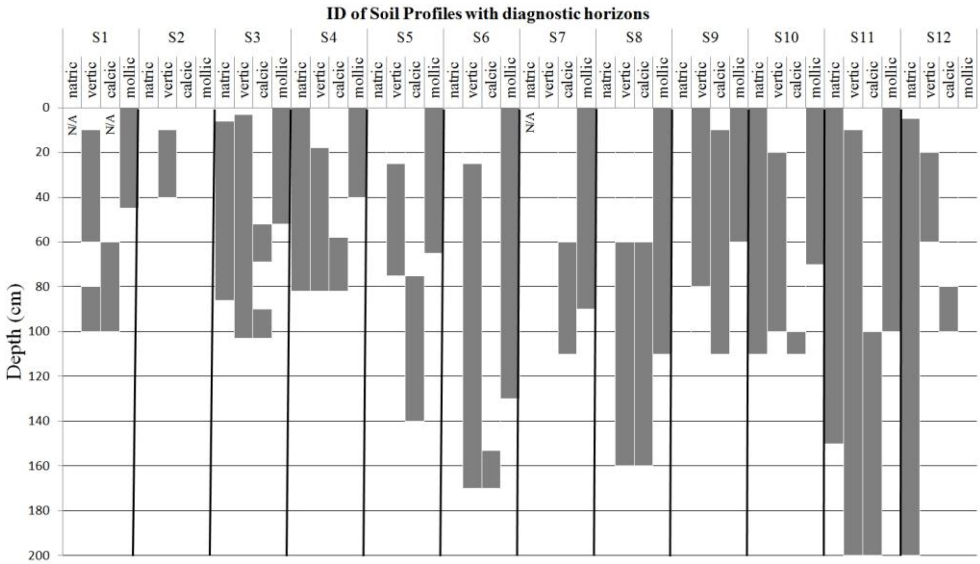

Figure 3:. Data based estimation of diagnostic horizons in investigated profiles.

Table 3 : Soil characteristics of the profiles representing the most typical soil conditions within the study area (S7–S9-S11)

Profile ID	Horizon depth	Texture of fine earth (<2 mm)	Grain size distribution in fine earth (%)			pH_{H2O}	pH_{KCl}	$CaCO_3$	Organic carbon	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC	ESP
	(cm)		(<2 mm) Clay (0.002 mm <) %	Silt (0.002-0.063 mm) %	Sand (0.063-2 mm) %			% (m/m)	%	$cmol \cdot kg^{-1}$	$cmol \cdot kg^{-1}$	$cmol \cdot kg^{-1}$	$cmol \cdot kg^{-1}$	$cmol \cdot kg^{-1}$	%
S7	0-10	*silt loam*	15.4	71.5	13.1	7.33	6.79	1.34	3.33	N/A	N/A	N/A	N/A	N/A	N/A
	10-25	*silt loam*	18.1	73.6	8.3	7.35	6.86	1.72	2.35	N/A	N/A	N/A	N/A	N/A	N/A
	25-40	*silt loam*	22.1	69.7	8.2	7.37	6.92	2.44	2.69	27.10	2.50	3.30	0.16	33.06	0.48
	40-60	*silt loam*	26	67.1	6.9	7.74	7.21	7.25	1.50	N/A	N/A	N/A	N/A	N/A	N/A
	60-75	*silty clay loam*	29.8	65.6	4.6	8.04	7.44	17.13	1.12	N/A	N/A	N/A	N/A	N/A	N/A
	75-90	*silty clay loam*	27.8	64.3	7.9	8.22	7.66	26.18	0.60	19.50	3.00	3.30	0.18	25.98	0.69
	90-105	*silt loam*	26.7	64.8	8.5	8.32	7.68	26.41	0.09	N/A	N/A	N/A	N/A	N/A	N/A
	106-110	*silt loam*	26	65.1	8.9	8.39	7.76	19.85	0.45	N/A	N/A	N/A	N/A	N/A	N/A
S9	0-10	*silty clay loam*	35.1	61.5	3.4	4.95	4.12	0	2.28	24.00	5.15	1.00	0.19	30.33	0.62
	30-40	*silty clay*	43.1	50.2	6.7	7.2	6.88	16.33	1.06	44.38	4.66	0.95	0.21	50.20	0.42
	50-60	*silty clay loam*	39.6	51.3	9.1	7.42	7.01	21.96	1.65	38.43	4.31	0.83	0.27	43.83	0.61
	70-80	*silty clay loam*	34.6	56.8	8.6	7.67	7.1	25.63	0.45	26.95	3.61	0.59	0.52	31.67	1.65
	100-110	*silty clay loam*	28.1	59.6	12.3	7.72	7.22	23.22	0.19	23.16	4.13	0.58	0.67	28.53	2.36
S10	0-10	*silt loam*	13.5	77.5	9	7.57	6.74	4.03	1.99	5.76	1.03	0.20	7.81	14.79	52.79
	10-20	*silt loam*	21.7	68.6	9.7	9.42	8.33	1.9	0.83	6.53	1.45	0.50	23.68	32.16	73.63
	20-30	*silty clay loam*	31.8	60.1	8.1	9.45	8.55	1.98	1.30	6.27	1.88	0.60	31.76	40.50	78.41
	30-40	*silty clay*	41.5	52.6	5.9	9.78	8.84	1.96	0.69	6.03	2.45	0.66	32.48	41.61	78.06
	40-50	*silty clay loam*	39.3	55.7	5	9.76	8.85	2.14	1.45	5.99	3.17	0.58	32.36	42.09	76.88
	50-60	*silty clay*	41.9	51.5	6.6	9.73	8.74	1.57	0.81	5.19	3.26	0.56	32.24	41.24	78.17
	60-70	*silty clay loam*	36.2	55.8	8	9.73	8.89	7.9	0.88	12.10	3.33	0.44	30.50	46.36	65.79
	70-80	*silty clay loam*	36.7	52.1	11.2	9.62	8.9	14.37	0.42	14.00	3.50	0.34	27.98	45.82	61.06
	80-90	*silty clay loam*	33.1	56.3	10.6	9.62	8.86	13.38	0.10	10.59	2.64	0.40	25.20	38.83	64.90
	90-100	*silty clay loam*	30.2	58	11.8	9.69	8.8	11.29	0.28	11.16	2.55	0.36	22.64	36.71	61.68
	100-110	*silty clay loam*	28.6	59.6	11.8	9.69	8.86	15.63	0.26	16.52	3.26	0.33	20.28	40.38	50.22

The results of reclassification also highlight the fact that the types/main types of the Hungarian soil classification system and the reference groups of WRB system cannot be completely corresponded to each other. However, until data collected by the WRB methodology are not available in large number and with adequate spatial frequency, the estimation carried out by the reclassification of archive data provides a good alternative for the field identification of WRB RSGs.

4. Conclusion

Using the automated WRB soil classification based on our own developed algorithms five profiles could be classified as Solonetz, four as Vertisol and the remaining three profiles keyed out as unknown reference soil group from the 12 investigated profiles. According to the correlation studies the types of the Hungarian taxonomy not to one but sometimes to three RSGs could be assigned with unknown probability. This did not allowed the unambiguous reference-group-level WRB classification based on the archived soil data. The approximation carried out with the help of ISRIC database also indicates more than one RSGs associated with a distinct location, but it predicts the probability of the occurrence of them. However, the spatial resolution is not adequate to draw an accurate map of the heterogeneity of soils. In the case of the proved profiles Vertisol, Solonchak and Solonetz RSG-s could be identified.

The results of the automatized reclassification of the archive data suggested that the RSG-s of WRB cannot be unambiguously approximated as a consequence of the different field surveying approach and methods. The different data collection structure strongly limits the reclassification possibilities as well, but at least it provides more accurate result comparing with the estimation of the RSGs by simple assigning according general correlation rules or prediction based on location and ISRIC database.

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