CHARACTERISTICS OF RENDZINA SOILS IN SERBIA AND THEIR WRB CLASSIFICATION

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Abstract: According to the Serbian official soil classification system, Rendzina is a soil *type* with an A-AC-C-R profile, developed on parent rock containing more than 20% of calcareous material (except soils with an A-R profile on hard pure limestone or dolomite). Previous investigations have shown that 29 Rendzina soil profiles from Serbia belong to the reference soil groups (RSGs) of *Leptosols*, *Regosols* and *Phaeozem*s according to the World Reference Base for Soil Resources (WRB 2015). The present study addresses the correlations among three WRB RSGs in terms of soil texture, mean weight diameter (MWD), total N content, and humus fractional composition using Principal Component Analysis (PCA). The objective is to better understand the mutual relationship between the classification soil units used in Serbia and the international WRB system. The results show that PCA cannot unequivocally distinguish between these three RSGs. *Leptosols* and *Regosols* are highly incoherent groups while the group of *Phaeozems* is highly coherent, leading to the conclusion that the physical and chemical properties of the soil profiles of *Phaoeozems* are specific. It is obvious that soil depth and color, which are the overriding factors in the differentiation of Rendzina soils into three WRB RSGs, had no significant effect on these properties. The results further show that soil properties such as texture, MWD, humus fractional composition, etc. cannot be used to correlate Rendzina soils from Serbia with WRB. Instead, careful correlation of individual soil profiles is needed based on quantitative soil data analysis as required by WRB.

Key words: Rendzina, WRB, texture, MWD, humus fractional composition, PCA.

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Introduction

There are a large number of national or regional soil classifications based on different principles. To facilitate international communication, the International Union of Soil Sciences (IUSS) has developed an international soil classification system – World Reference Base for Soil Resources (WRB) (IUSS Working Group WRB, 2015). Since its inception in 1988, many correlations between national soil classifications and WRB have been reported. It is usually very difficult to simply assign a classification unit of the national classification system to only one WRB reference soil group (RSG) (Balla et al., 2016; Zádorová and Penížek, 2011). This is the case with the soil type called Rendzina. From the very beginning (Kubiena, 1953), the term Rendzina referred to soils with an A-C profile, developed on limestones and dolomites, and Pararendzina meant soils developed on silicate-carbonate substrates like loess, marl, fluvio-glacial material, and alluvium. Even today, in many national soil classifications, Rendzina and/or Pararendzina denote soils formed on different calcareous parent material (Florea and Munteanu, 2000; Němeček and Kozak, 2002; Шишов et al., 2000; etc.). Internationally, the term Rendzina (along with many others) has not been used since the establishment of the revised legend of the FAO soil map of the world (FAO, 1988) and WRB (IUSS Working Group, 2015). According to the revised legend of the FAO soil map of the world (FAO, 1988) and all WRB editions from 1998 to 2015 (IUSS Working Group, 2015), Rendzinas from many national soil classifications belong to the RSG of *Leptosols* developed on calcareous rocks. Based on other literature sources (Balla et al., 2016; Krasilnikov and Arnold, 2009; Krasilnikov et al., 2013; Kyrylchuk, 2017; Shishkov and Kolev, 2014; Zádorová and Penížek, 2011), the correlation between Rendzinas/Pararendzinas and WRB is much more complex. Besides *Leptosols*, Rendzinas correspond to many other RSGs, such as *Phaeozems*, *Regosols*, *Arenosols*, *Umbrisols* and *Cambisols*.

According to the Serbian official soil classification system (Škorić et al., 1985), Rendzina is a soil *type* within the *order* of automorphic soils and the *class* of humus-accumulative soils with an A-AC-C-R profile. Rendzina includes soils developed on parent rock containing more than 20% of calcareous material (except soils with an A-R profile on hard pure limestone or dolomite, which are classified as a distinct soil type: Limestone-Dolomite Black Soil). The classification of 29 Rendzina soil profiles from Serbia according to WRB 2015 (IUSS Working Group WRB, 2015) in Radmanović et al. (2017) shows that they belong to *Leptosols* (41% profiles), *Regosols* (35%) and *Phaeozems* (24%). The question is what caused the separation of a single soil type, Rendzina, into three RSGs. The classification of soils according to WRB is based on soil properties defined in terms of diagnostic horizons, diagnostic properties, and diagnostic materials (IUSS Working Group WRB, 2015). In this respect, soil depth, color (dry and moist),

coarse fragments, soil organic carbon (SOC), CaCO$_3$, pH, and base saturation were needed for the classification of Rendzinas according to WRB (Radmanović et al., 2017). Soil depth and color were the dominant soil properties in separating Rendzinas into three RSGs. Soil depth caused the first differentiation between *Leptosols* and *Phaeozems*, while soil (moist) color led to the second differentiation between *Phaeozems* and *Regosols*. The paper examines whether these three RSGs also differ in terms of other soil characteristics (not used as WRB criteria), such as texture, structure, and humus fractional composition. The correlations among the three WRB RSGs in this regard were tested using PCA in order to better understand the relationship between the soil classification system used in Serbia and the international WRB soil classification system.

Materials and Methods

A total of 29 Rendzina soil profiles from different parts of Serbia were studied. The location, topography, parent material, carbonate status, and land use of the investigated soils are shown in Table 1.

Table 1. General site information and main soil formation factors.

Pr.	Location	Altitude (m a.s.) landform	Parent material	Variety	Land use
		Leptosols			
1	east	199, hill top	soft limestone	calcareous	forest
2	east	199, hill top	soft limestone	calcareous	forest
5	east	199, hill top	soft limestone	calcareous	grassland
9	east	250, gentle slope	soft limestone	calcareous	arable land
11	southwest	1210, slope 40°	marly limestone	calcareous	grassland
12	northwest	190. hill top	sandy marl	calcareous	grassland
16	west	443, slope 55°	soft limestone	calcareous	forest
17	west	560, hill top	soft limestone	decarbonated	grassland
18	central	261, hill top	soft limestone	calcareous	forest
19	central	240, slope 20°	soft limestone	calcareous	arable land
20	central	290, slope 60°	soft limestone	decarbonated	forest
29	southeast	370, slope 80°	calcareous marl	calcareous	forest
Pr.	Location	Altitude (m a.s.) landform	Parent material	Variety	Land use
		Phaeozems			
3	east	199, hill top	soft limestone	calcareous	grassland
4	east	199, hill top	soft limestone	calcareous	grassland
6	east	199, hill top	soft limestone	calcareous	grassland
7	east	199, gentle slope	soft limestone	decarbonated	forest
8	east	199, gentle slope	soft limestone	calcareous	grassland
10	east	250, gentle slope	marly limestone	decarbonated	arable land
22	southeast	438, slope 45°	marly limestone	calcareous	forest

Table 1. Continued.

		Regosols			
13	northwest	187, slope 60°	sandy marl	calcareous	grassland
14	west	172, hill top	marl	calcareous	arable land
15	west	151, slope 60°	marl	calcareous	forest
21	central	280, footslope	soft limestone	decarbonated	grassland
23	southeast	375, slope 60°	sandy marl	calcareous	forest
24	southeast	370, slope 30°	sandy marl	calcareous	arable land
27	southeast	337, footslope	soft limestone	calcareous	arable land
28	southeast	335, slope 45°	marly limestone	calcareous	grassland
30	southeast	720, slope 40°	soft limestone	calcareous	forest
31	southeast	715, slope 30°	soft limestone	calcareous	arable land

The study examined the following physical and chemical properties of the soils from the A horizon: texture, pH and total N using common methods (Van Reeuwijk, 2002), mean weight diameter (MWD) according to Le Bissonais (1996), and humus fractions using the Ponomarieva and Plotnikova method (Пономарева and Плотникова, 1968), where humic acids (HA), fulvic acids (FA) and humin are expressed as a percentage of SOC.

The objective of the Principal Component Analysis (PCA) of normally distributed soil properties was to verify the WRB classification of the soil samples. PCA was selected because of its numerous advantages. Primarily, it is an unsupervised method that is extremely informative when the structure of a set of input data is examined in maximum variance space. The analysis was performed using the IBM SPSS Statistics 19 software package.

Results and Discussion

As previously stated, Rendzina is a soil *type* according to the Serbian official soil classification system (Škorić et al., 1985). A soil type is the central unit of that soil classification, defined by the characteristic sequence of genetic horizons, soil-forming processes and qualitatively similar physical and chemical properties of the horizons. Heterogeneity within a soil type is represented by lower classification units: subtype, variety and form. Thus, all Rendzina profiles examined in this study belong to the same *subtype* – marl, marly limestone and soft limestone (the most widespread subtype in Serbia); three *varieties* – calcareous, decarbonated and colluvial; and several *forms* – mostly loamy, low to medium skeletal. These Rendzina soils have been divided into three WRB RSGs (Radmanović et al., 2017). According to the IUSS Working Group WRB (2015), the dominant identifiers, i.e. the soil-forming factors or processes that most clearly influence these RSGs, are: *Leptosols* – soils with root growth limitations, thin or with many coarse fragments; *Phaeozems* – pronounced accumulation of organic matter in the mineral topsoil,

dark topsoil, no secondary carbonates (unless very deep), high base status; and *Regosols* – no significant profile development. Based on the two soil classifications, the investigated Rendzina soil profiles differ considerably from each other. It is well-known that the Rendzina soil characteristics examined in this study (texture, structure, total N content and humus fractional composition) are very important because they are closely related to soil-forming factors and processes (i.e. to other physical and chemical properties), so these properties would be expected to differ in the three RSGs.

Statistical descriptions of the studied soil characteristics are provided in Table 2.

Table 2. Rendzina soil properties (A horizon).

Soil properties	*Min.*	*Max.*	*Mean*	*SD*
Leptosols (*n=12*)				
Sand (%)	20.4	70.2	39.7	13.6
Silt (%)	20.2	42.6	29.0	7.7
Clay (%)	8.0	44.8	31.1	11.0
MWD	0.0	2.5	1.4	0.9
pH	7.2	8.1	7.6	0.2
N (%)	0.1	0.5	0.4	0.1
HA (%)	18.3	35.7	27.9	4.9
FA (%)	26.9	41.1	37.0	4.2
Humin (%)	25.2	45.8	35.1	6.3
Phaeozems (*n=7*)				
Sand (%)	39.1	53.5	45.1	5.9
Silt (%)	16.2	28.6	21.2	4.2
Clay (%)	27.7	39.2	33.4	3.9
MWD	0.9	1.9	1.4	0.4
pH	7.0	7.7	7.5	0.3
N (%)	0.2	0.5	0.3	0.1
HA (%)	24.8	30.1	26.8	2.0
FA (%)	29.5	37.0	32.9	3.1
Humin (%)	35.4	44.6	40.3	2.8
Regosols (*n=10*)				
Sand (%)	28.0	68.7	45.1	13.9
Silt (%)	20.0	41.1	28.2	6.7
Clay (%)	9.8	42.4	28.1	11.5
MWD	0.7	2.3	1.4	0.4
pH	7.6	8.0	7.7	0.1
N (%)	0.1	0.5	0.3	0.1
HA (%)	24.8	33.9	29.2	3.4
FA (%)	32.2	45.1	37.2	4.7
Humin (%)	25.0	68.6	38.1	12.0

After verifying the normality (the Shapiro–Wilk test), the studied physical and chemical parameters were treated with multivariate analysis tools to gain the fullest possible insight into the structure of the RSG datasets and any discrimination among them. Sand, silt, clay, MWD, pH, HA, FA and humin were the parameters used to assess the discrimination informativity of the RSGs. Transformation into the maximum variance space retained slightly more than 74% of the dataset structure information.

As a result, Figure 1 (PC1-PC2-PC3) provides sound information about the structure of the RSG datasets. It is obvious that there is a plane in the maximum variance space where the RSGs could be unequivocally differentiated. At the same time, *Leptosols* and *Regosols* are extremely incoherent.
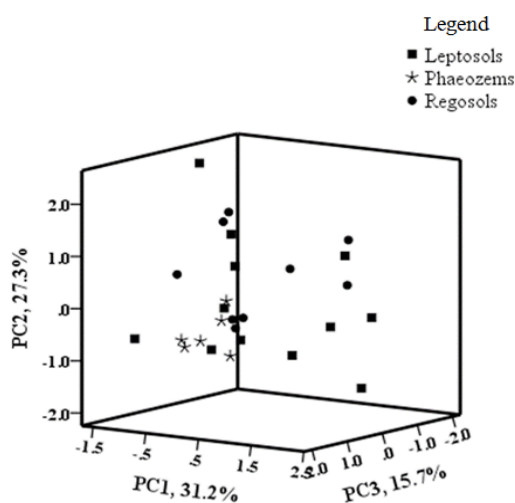

Figure 1. The scores plot of Rendzina soil properties.

This is a consequence of equal contributions of all the parameters assessed under PC2 to the total variance of the dataset. In absolute terms, the values of *Loadings* under PC2 (bold in Table 3) are very close and have a considerable effect on the incoherence of the groups of samples identified as *Leptosols* and *Regosols*.

The PCA results showed that the three WRB RSGs had not been separated. In other words, there was no substantial difference between them in terms of the studied physical and chemical parameters. As such, *Leptosols* and *Regosols* were very incoherent, possibly due to WRB classification requirements. In the case of *Leptosols*, soil depth did not affect the studied physical and chemical properties even though it is an important agroecological factor. The *Regosols* RSG was distinguished by soil color. Lighter shades of Regosols are probably due to lower SOC or higher $CaCO_3$ concentrations, but neither soil parameter had a significant effect on the studied physical and chemical properties.

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Table 3. PCA loadings of Rendzina soil properties.

Soil properties	PC		
	1	2	3
Sand	-0.787	0.483	-0.291
Silt	0.835	0.102	-0.184
Clay	0.362	**-0.646**	0.593
MWD	0.401	**-0.554**	-0.299
pH	-0.081	**0.540**	0.319
HA	0.317	**0.666**	0.510
FA	0.586	0.288	-0.578
Humin	-0.659	**-0.629**	-0.049

The variance of the humin parameter was characteristic of the extremely coherent *Phaeozems* RSG. A separate analysis of the physical and chemical parameters (Figure 2) was undertaken to examine the source of this RSG's coherence.

The conserved variance in the maximum variance space of the physical properties was 99.4%, so Figure 2a is an extremely good representation of the RSG dataset structures. It is apparent that the coherence of the *Phaeozems* RSG was conserved and that the small variance of the silt parameter contributed to the result. The coherence of the *Phaeozems* RSG in the maximum variance space of the chemical properties was slightly disturbed (Figure 2b), but it is obvious that the variance of the humin parameter was characteristic of the *Phaeozems* RSG. The coherence of the *Phaeozems* RSG might be pronounced because of the smallest number of soil profiles, but likely also due to the fact that all the soil profiles originated from eastern and southeastern Serbia and were developed on similar parent materials and in comparable climate conditions.

As previously indicated, a lot of attention in the field of soil science has recently been devoted to potential correlations between national soil classifications and WRB (Kabala et al., 2016). There have especially been attempts to directly associate a classification unit of the national classification system with the equivalent WRB

RSG (Krasilnikov and Arnold, 2009), or use available data from national soil archives to classify soils according to WRB (Balla et al., 2016).
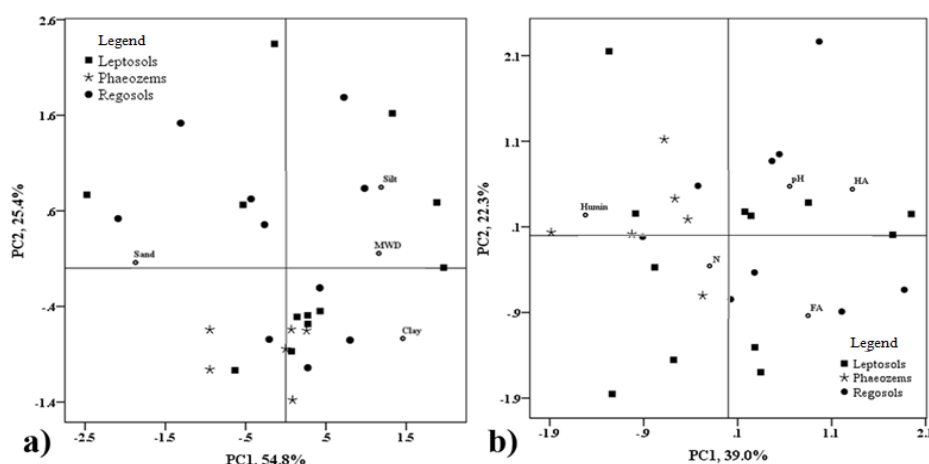

Figure 2. The scores plots of Rendzina soils: a) physical and
b) chemical parameters.

The results of the present study showed that PCA of the investigated physical and chemical parameters of Rendzina soils did not recognize the WRB *Leptosols*, *Phaeozems* and *Regosols* RSGs. Consequently, in the case of these types of soil (and potentially other types as well), it is not possible to establish correlations based on the examined physical and chemical data. In addition, the results of the present study corroborate the conclusions of other authors (Kabala et al., 2016; Reintam and Köster, 2006; Zádorová and Penížek, 2011) that a careful correlation of individual soil profiles is needed based on analyses of quantitative soil data as required by WRB.

Conclusion

Previous investigations have shown that 29 Rendzina soil profiles from Serbia belong to the RSGs of *Leptosols*, *Regosols* and *Phaeozems* according to WRB 2015. The present study tested the correlations among these WRB RSGs in terms of soil texture, MWD, total N content, and humus fractional composition using PCA. The results showed that PCA cannot make an unequivocal distinction between the three RSGs. In addition, *Leptosols* and *Regosols* are extremely incoherent and *Phaeozems* extremely coherent, which leads to inferences about the specific nature of their physical and chemical properties. It is clear that soil depth and color, which drove the differentiation of the Rendzina soil type into three WRB

RSGs, had no significant effect on the properties tested in this research. The results further indicated that data on soil properties such as texture, MWD, and humus fractional composition cannot be used to correlate Serbia's classification of Rendzina soils with WRB. Therefore, a careful classification of individual soil profiles is needed, based on analyses of quantitative soil data as required by WRB.

Acknowledgements

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KARAKTERISTIKE RENDZINA U SRBIJI I NJIHOVA KLASIFIKACIJA PREMA WRB SISTEMU

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R e z i m e

Prema zvaničnoj klasifikaciji zemljišta Srbije prema Škoriću i saradnicima, rendzina je *tip* zemljišta građe profila A-AC-C-R, čiji matični supstrati sadrže više od 20% karbonata (izuzev zemljišta građe profila A-R, obrazovanih na čistim tvrdim krečnjacima i dolomitima). Prethodna istraživanja su pokazala da 29 profila rendzine sa područja Srbije, prema međunarodnoj WRB klasifikaciji zemljišta iz 2015. godine, pripadaju referentnim grupama zemljišta (RSG): *leptosola, faozema* i *regosola*. U ovom radu je testiran međusobni odnos izdvojenih WRB RSG prema teksturi, prosečnom masenom prečniku (MWD), sadržaju ukupnog N i frakcionom sastavu humusa, metodom analize glavnih komponenti (PCA), a sve s ciljem boljeg razumevanja međusobnog odnosa klasifikacionih jedinica domaćeg i međunarodnog WRB sistema za klasifikaciju zemljišta. Rezultati su pokazali da PCA ne može na nedvosmislen način da razlikuje ove tri referentne grupe zemljišta. Pri tome su RSG *leptosola* i *regosola* veoma nekoherentne, dok je RSG *faozema* izrazito koherentna što ostavlja prostora za zaključak o specifičnosti fizičkih i hemijskih osobina rendzina koje pripadaju *faozemima*. Očito je da dubina i boja zemljišta, koje su bile presudne za diferenciranje zemljišta *tipa* rendzina na tri WRB RSG, nisu imale značajan uticaj na osobine ispitivane u ovom radu. Rezultati su nadalje pokazali da podatke o osobinama zemljišta kao što su tekstura, MWD, frakcioni sastav humusa, itd., nije moguće koristiti za korelaciju zemljišta tipa rendzina u Srbiji sa WRB sistemom klasifikacije, već je neophodna pažljiva klasifikacija svakog pojedinačnog profila zemljišta bazirana isključivo na kvantitativnim podacima koje je WRB sistem predvideo svojim zahtevima.

Ključne reči: Rendzina, WRB, tekstura, MWD, frakcioni sastav humusa, PCA.

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