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HUMUS COMPOSITION OF RENDZINA SOILS IN DIFFERENT ENVIRONMENTAL CONDITIONS OF SERBIA

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ABSTRACT

This paper shows organic matter composition (humic acids, fulvic acids, humins) and fractions of humic (free and bounded with mobile R_2O_3 (HA1), bounded with Ca (HA2), and bounded with clay and stabile R_2O_3 (HA3)), and fulvo acids (free and bounded with mobile R_2O_3), bounded with HA1, bounded with HA2, and bounded with HA3), in Rendzina soils on different altitudes (151-1210 m), landforms (hilltop, flat or very gentle slope; foot slope, very gentle slope, south, southwest; slope 45-80º, south, southeast, southwest; slope 20-60º, north, northwest, northeast), and regions (Srem, west, central, east and southeast Serbia).

Differences in temperature and water regimes of Rendzinas on various altitudes are not so prominent to have a significant impact on organic matter composition. Landform has more significant impact, with average higher content of HA on slopes, and FA on flat positions, which could be attributed to reduced wetting of soils on slopes. Exposition had no significant impact on humus composition. Differences in soil moisture among regions are more pronounced than differences in soil temperature.

Differences in soil organic matter composition among Rendzinas from various regions are small and do not follow pattern of humidity change. Still, organic matter of Rendzina from most humid western region has the least favourable HA/FA ratio, while at the driest east and southeast regions content of humin is the greatest.

Key words: *humic acids, fulvic acids, humins, altitude, landform, regions*

INTRODUCTION

Soil organic matter (SOM) plays an essential role in ecosystem dynamics. It influences a large set of soil chemical, physical and biological properties. These properties have an impact on vegetation, fauna and ecosystem functions, such as nutrient cycling, carbon sequestration and pollutant retention. SOM composition is influenced by a variety of factors, but it is generally recognized that climate, especially temperature and precipitation, is the most important factor regulating SOM [1]. Altitude is often employed to study the effects of climatic variables on SOM dynamics [2]. Topographical aspects also induce local variation in temperature and precipitation [3].

While the effects of climate and vegetation on total carbon stocks have been studied intensively, detailed data linking SOM composition to biome-scale dynamics are much more scarce. This makes it difficult to identify patterns and generalities regarding the SOM chemistry response to environmental change [1].

According to soil classification of Škorić [4]. Rendzinas have mollic A horizon that gradually transits to loose calcareous C horizon. Rendzinas are present in almost all parts of Serbia, on various calcareous parent materials (except on massive limestone and dolomites), altitudes and land forms. They are under various forest and grass communities or are cultivated. Hitherto research have shown that carbon content and organic matter composition are influenced by leaching of carbonates and basic cations, and also by the change in land use [5,6,7].

With regard to Rendzinas importance for Serbian soil recourses, our research was aimed to detect influence of climate, altitude and landform on SOM composition. Our results should point out soil organic matter sensitivity to climate in the past, considering climate change prediction for different regions in Serbia [8,9], and should assist in monitoring of future dynamics of soil organic matter composition.

MATERIAL AND METHODS

In various regions of Serbia, 24 soil profiles were opened to examine humus composition of A horizon. This horizon was 14-30 cm thick, so one or two disturbed samples were taken from each, giving 41 soil samples altogether. Table 1 shows three ways of data grouping: 5 altitude groups, 4 landform groups and 5 regions. For each Rendzina group, the most important environmental conditions shown are: altitude, parent material, average annual temperature, average annual precipitation, land use (forest, grass land, arable land) and basic characteristics of vegetation.

Particle size distribution was determined by pipette method; pH in water (soil:water ratio 1:2.5) [10,11]; organic matter composition was determined by the method of Ponomareva and Plotnikova [12]. This method includes assessment of three humic acids fractions, four fulvic acids fractions and total humins (HU). Humic acids fractions are: free and bounded with mobile R_2O_3 (HA1), bounded with Ca (HA2), and bounded with clay and stable R_2O_3 (HA3).

Total humic acids (HA) were determined by summing up HA1, HA2 and HA3. Fulvic acids fractions are: free and bounded with mobile R_2O_3 (FA1a), bounded with HA1 (FA1), bounded with HA2 (FA2), and bounded with HA3 (FA3). Total fulvic acids (FA) were calculated by summing up of FA1a, FA1, FA2 and FA3. Content of each fraction was calculated as a percentage of the total C. Humic acids to fulvic acids ratio was calculated as HA/FA.

Average values of the results of our research are presented within this paper. T-test was used to examine if there were significant differences in organic matter composition of Rendzina from different altitudes, landforms and regions.

RESULTS

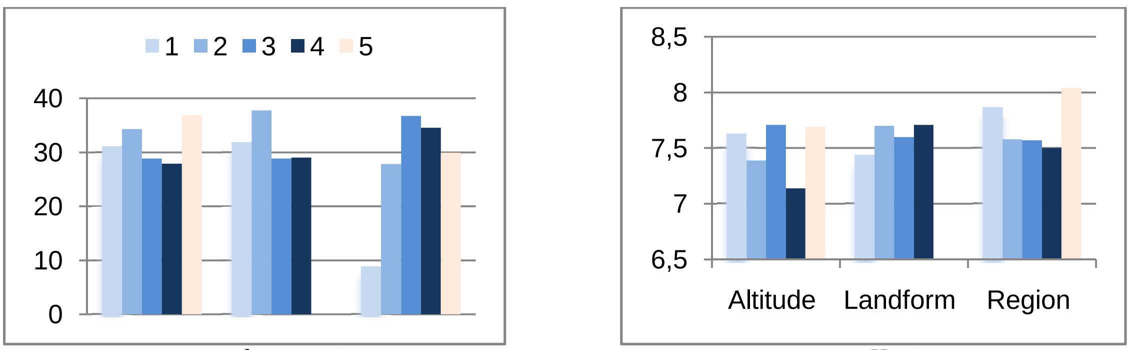
Table 1 shows Rendzina soil is formed in various environmental conditions. Its characteristics, such as organic matter composition, were formed under the influence of various carbonate parent materials, altitudes, topographical aspects, climate conditions and land use types, natural vegetation. Organic matter composition depends on environmental conditions and soil properties (clay content and pH value).

Average clay content and pH values of Rendzina groups are presented in Figure 1. Since humus composition is influenced by carbonate and base leaching, we performed statistical analysis of total Rendzinas, and separately in calcareous Rendzinas (number of sampled decarbonated Rendzinas was insufficient to make valid analysis). Average humus content was similar in both total and calcareous Rendzinas. Figures 2, 3 and 4 show humus composition of total Rendzinas on different altitudes, landforms and regions, respectively.

Table 1 General environmental parameters

Group	No.	Altitude (m a.s)	Parent material[b]	MS[a]	Precipitation (mm)	Temperature (ºC)	Land use/ Vegetation
				REGION			
Srem	1	187-190	sm	1	656.2	11.36	G[c](2) lush
West and southwest	2	151-1210	m, sl	2, 3	814.9-768.4	11.37-6.62	F[d](2), G(2) lush; A[e](1)
Central	3	240-290	sl	4	698.2	11.70	F[d](2), G(1) lush; A(1)
East	4	199-250	sl	5	652.6	11.71	G(6) lush; F[d](3), A(3)
Southeast	5	335-720	sm, cm, ml, sl, cg	6, 7	592.9-605.8	11.39	F[f](5), A(3), G(1) scarce
				ALTITUDE			
Calcareous	1	<200	m, sm, sl	1, 5, 2	656.2-652.6	11.36-11.71	G(7), F(39), A(1)
	2	200-300	sl	2, 4, 5	652.6-814.9	11.71-11.37	A(2), F(1)
	3	300-400	cm, sm,sl	7(4)	605.8	11.39	F(2), A(2), G(1)
	4	400-700	ml, sl	2, 6	592.9-814.9	11.37-11.40	F(2)
	5	>700	ml, sl	3, 6	768.4-592.9	6.62-11.40	F(1), G(1), A(1)
Decarbonated	1	<200	sl	5	652.6	11.71	F(1)
	2	200-300	sl	4, 5	652.6-698.2	11.71	G(2), A(2), F(1)
	4	400-700	sl, cg	2, 7	605.8-814.9	11.37	F(1), G(1)
				LANDFORM/exposure			
hill top, flat or very gentle slope							
	1	172-560	sl, m, sm, cg	5, 2, 1, 4, 7	605.8-814.9	11.36-11.71	F(5), G(6), A(3)
footslope, very gentle slope, south, southwest							
	2	280-337	sl	4, 7	605.8-698.2	11.37-1.,70	G(1), A(1)
slope 45-80º, south, southeast, southwest							
	3	151-438	ml, sl, m, sm, cm	7, 1, 2, 4, 6	592.9-814.9	11.36-11.70	F(4), G(2)
slope 20-60º, north, northwest, northeast							
	4	240-1210	sl, sm, ml	2, 6, 7, 3, 4	592.9-814.9	6.62-11.70	F(3), G(1), A(3)

[a] Meteorological data [10] for station: 1-Rimski šančevi, 2-Valjevo, 3-Sjenica, 4-Beograd, 5-Negotin, 6-Niš, 7-Pirot. [b] m-marl, cm-calcareous marl; sm-sandy marl, ml-marly limestone , sl-soft limestone, cg-calcareous gravel. [c] F - forest; G - grassland; A – arable land. [d] Forest, closed tree canopy, species: Turkey oak (*Quercus cerris* L.,) Downy oak (*Quercus pubescens* Willd.), rarely Hawthorn (*Crataegus spp.*), Hornbeam (*Carpinus spp.*) and Ash (*Fraxinus spp.*); in Oplenac park: Black pine (*Pinus nigra* Arnold). [e] On arable land there is a rotation of small grains and maize.
[f] Degraded forest and shrubs, species: Oak, Hawthorn and European wild pear (*Pyrus pyraster* Burgsd.)



clay   pH

Figure 1 Average clay content and pH values in Rendzina soils of Serbia on different altitudes (m): 1 <200, 2 200-300, 3 300-400, 4 400-700, 5 >700; landforms (1-hilltop, flat or very gentle slope; 2-footslope, very gentle slope, south, southwest; 3- slope 45-80º, south, southeast, southwest; 4- slope 20-60º, northern, northwest, northeast), and regions (1-Srem, 2-west 3-central, 4-east, 5-southeast)

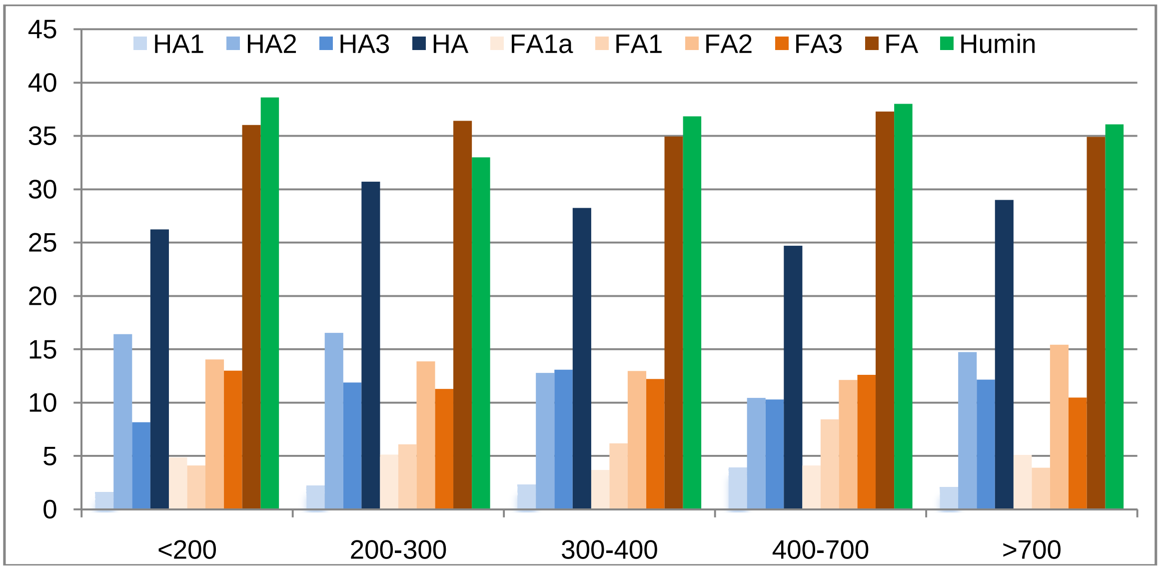


Figure 2 Average humus composition (%) in Rendzina soils of Serbia on different altitudes (m)

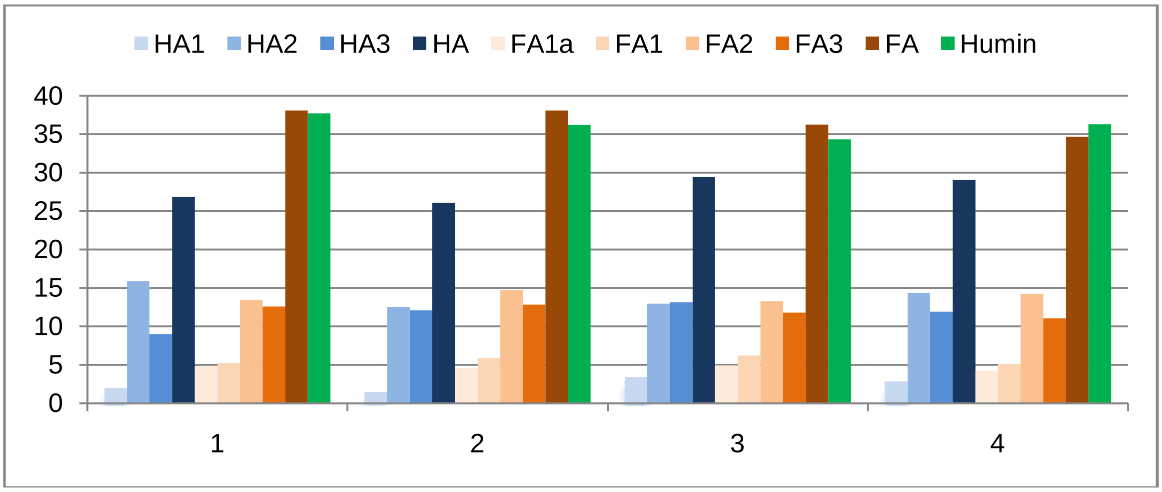


Figure 3 Average humus composition in Rendzina soils of Serbia on different landforms (1-hilltop, flat or very gentle slope; 2-footslope, very gentle slope, south, southwest; 3- slope 45-80º, south, southeast, southwest; 4- slope 20-60º, north, northwest, northeast)

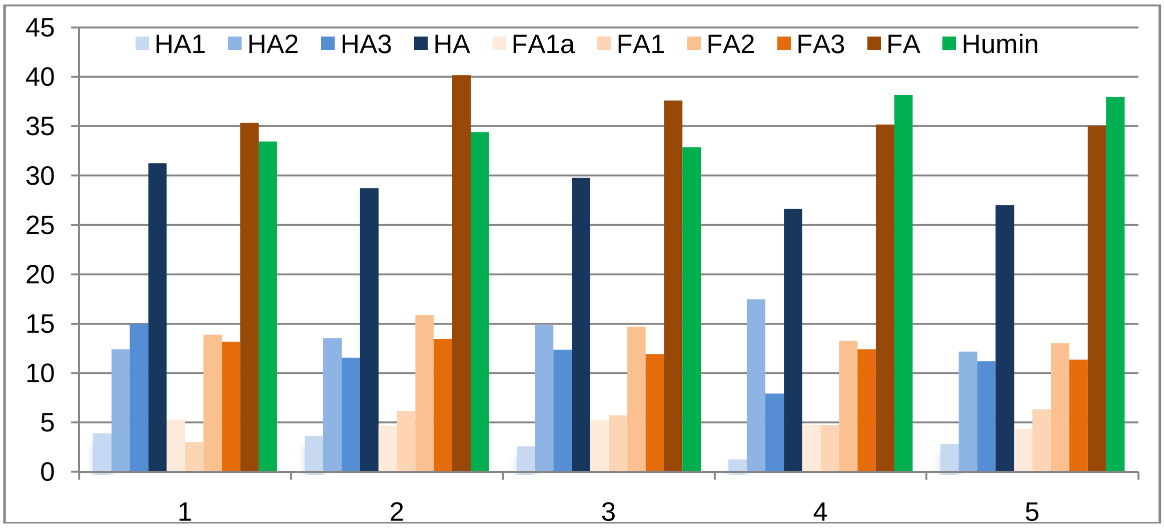


Figure 4 Average humus composition in Rendzina soils of different Serbian regions
(1-Srem, 2-west 3-central, 4-east, 5-southeast)

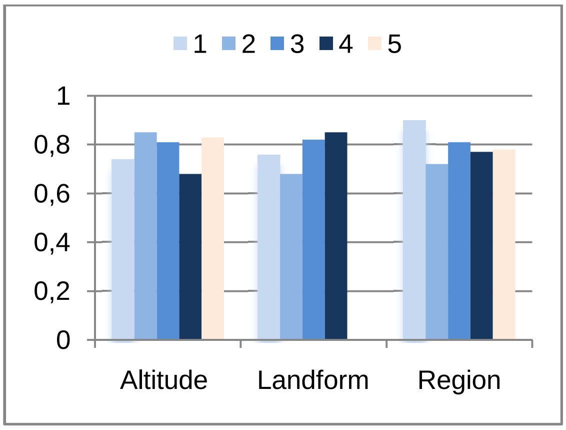


Figure 5 Average humic acids to fulvic acids ratio in Rendzina soils of Serbia; Altitudes (m): 1 <200, 2 200-300, 3 300-400, 4 400-700, 5 >700; Landforms: 1-hilltop, flat or very gentle slope; 2-footsope, very gentle slope, south, southwest; 3- slope 45-80°, south, southeast, southwest; 4- slope 20-60°, north, northwest, northeast; Regions: 1-Srem, 2-west, 3-central, 4-east, 5-southeast

Figure 5 shows HA/FA ratio for different altitudes, land forms and regions. Table 2 shows differences in humus composition among studied Rendzinas (fractions are not presented, since they showed no significant differences).

Table 2 Statistical significance of humus composition among Rendzinas of various altitudes, landforms and regions (*p<0.05, **p<0.01)

t	Clay	HA1	HA2	HA3	HA[d]	FA1	FA2	FA3	HA/FA
Altitude[a]									
2 vs. 1	-0.23	3.42**	-0.76	4.31**	2.62*	0.95	-0.17	-1.93	2.47*
3 vs. 1	-0.80	0.61	-1.68	4.24**	1.52	1.41	-1.07	-1.79	1.81
3 vs. 2	-1.07	0.12	-1.62	0.58	-1.26	0.75	-2.27	0.45	-0.48
4 vs. 1	-1.36	2.51	-5.21**	2.09	0.31	2.10	-1.05	-1.39	0.54
4 vs. 2	-1.43	1.79	-7.12**	-2.72*	-5.20**	2.85*	-4.32**	0.76	-2.51
4 vs. 3	-0.31	1.61	-0.84	-3.66*	-1.27	1.83	-0.61	0.43	-1.52
5 vs. 1	0.90	2.09	-0.80	8.92**	3.75*	-2.20	2.09	-3.44	4.59*
5 vs. 2	0.12	1.44	-2.07	-0.84	-1.80	1.38	-2.04	-0.32	-2.05
5 vs. 3	2.98*	-2.13	0.92	-2.64	-0.44	-6.06**	2.67	-2.90	-0.67
5 vs. 4	3.56*	-1.37	1.43	5.73*	1.73	-2.71	1.89	-1.08	1.67
Landform[b]									
1 vs. 2	-2.90	-1.64	0.99	-8.22*	-0.86	0.68	-16.05*	2.91	-0.89
1 vs. 3	3.84*	-3.86*	2.91*	-2.22	-1.45	-0.48	-0.02	8.86**	-1.65
1 vs. 4	1.95	-2.96*	2.98*	-3.73**	-2.23	-0.48	-0.85	2.72*	-3.76**
2 vs. 3	6.48*	-1.48	-0.64	-1.49	-2.32	1.16	0.36	4.63*	-1.56
2 vs. 4	3.82	-2,27	0.79	0.72	-0.19	-0.90	2.74	-0.10	-0.30
3 vs. 4	0.79	-0.02	0.09	2.89*	0.85	0.29	-0.11	0.09	0.06
Region[c]									
1 vs. 2	-1.55	-0.78	-0.37	1.54	1.20	-4.19	-1.42	-0.23	0.77
1 vs. 3	-7.34	6.36	-1.67	0.49	-0.04	0.24	-2.19	0.87	-0.70
1 vs. 4	-4.47*	8.65	-5.25	9.90	2.79*	-3.83	1.27	-0.72	2.78
1 vs. 5	-1.13	-0.31	0.10	3.09	1.15	-3.90	1.75	0.47	0.20
2 vs. 3	-1.67	0.71	-0.41	-0.31	-0.03	-0.14	1.47	0.67	-0.58
2 vs. 4	-1.36	6.31**	-1.63	8.31**	2.61	0.39	1.73	-1.12	1.36
2 vs. 5	0.85	0.32	3.81*	-1.39	0.60	-0.07	2.24	1.76	-3.30*
3 vs. 4	0.59	1.82	-0.81	8.73**	3.43*	-0.18	2.52	-2.05	8.54**
3 vs. 5	3.59*	-0.87	2.05	-0.17	0.69	-0.17	4.14*	0.13	-0.19
4 vs. 5	1.99	-3.5**	4.16**	-4.39**	-1.41	-2.83*	0.03	2.24*	-0.89

[a] Altitude (m): 1 <200, 2 200-300, 3 300-400, 4 400-700, 5 >700. [b] Landform: 1-hilltop, flat or very gentle slope; 2-footslope, very gentle slope, south, southwest; 3-slope 45-80°, south, southeast, southwest; 4- slope 20-60°, north, northwest, northeast. [c] Region: 1-Srem, 2-west, 3-central, 4-east, 5-southeast. [d] HA-humic acids, FA-fulvic acids.

DISCUSSION

Increase of altitude had no regular impact on changes of average humus content in Rendzinas. Significant increase of total HA, i.e. wider HA/FA ratio is at >700 m compared to lowest altitude <200 m. Increase of altitude in most cases causes significant decrease of HA2 content and increase of HA3 (except on 400-700 m). Dynamics of some organic matter fractions along altitude cannot be connected with clay size fraction content or pH values of soil. Land use has significant influence on organic matter composition in Rendzinas of Serbia [6]. Rendzinas under forest are dominant on lower altitudes, while on higher altitudes Rendzinas under forest, grassland and arable are equally present, so actual differences in organic matter composition on various altitudes cannot be accredited to direct influence of land use.

Temperature and water regimes of soils are considered to be environmental factors in the metabolism of organic matter [13]. Generally, temperature decreases and precipitation increases with increasing altitude which influences the composition and productivity of vegetation and, consequently, affects the quantity and turnover of SOM [14]. Results [13,15] show that an increase of temperature under sufficient amount of precipitation caused increase of content of total carbon, HA and insoluble residue. Ma et al. [16] claim that from the foot to the top hill, the value of HA/FA has gradual increase trend, and the progressive increase rate is manifested above 1000 m a.s.l. in the surface soil layer (humid and semi-humid climate, vegetative cover mainly forest). Results of Miralles et al. [17] show that increased accumulation of extractable humic fractions and nearly uniform HA/FA was found in the intermediate range of the altitudinal series. Lower amount of HA compared to FA and humin was found at lower altitudes. Miralles et al. [17] say that total solar radiation and sunlight hours could be associated with pronounced seasonal moisture changes, which is believed to favour the formation and maturation of humic acids. Some authors found no differences among various altitudes [18]. Climatic conditions on various altitudes in Serbia are not different enough to cause significant influence on organic matter composition, neither on organic matter content [19].

Average HA/FA ratio is as follows: northern slopes > southern slopes > hilltop > footslope. Statistically, it is significantly higher on northern slopes compared to hilltop. Content of humic acids is higher in Rendzinas on the slopes compared to Rendzinas on the flat positions 1 and 2, while fulvic acid content is higher on flat positions. Rendzinas on hill top have significantly higher content of mobile HA1, and significantly lower content of HA2 stabile fraction of humic acids, compared to Rendzinas on the slopes. There were no significant differences in fractions of fulvic acids in Rendzinas on different landforms. Significantly higher content of FA3 fraction of fulvic acids on flat positions 1 and 2 is caused by significantly higher amount of clay of those Rendzinas. Average humin content is as follows: hill top > northern slopes > footslope > south slopes, but with insignificant differences.

According to Vorob'eva [13], vegetation and soil on slopes with different exposures and steepness are influenced by their hydrothermal conditions. In other words, lower temperatures and higher precipitation cause organic C increase in soil (actually, labile forms of C), while higher temperatures and lower precipitation cause mobile forms to become stabilized. Results of Prikhod'ko et al. [20] show that the slope soils differed from the watershed soils by the smaller amounts of humic and fulvic acids, and by the greater content of humin carbon. Our results show that humus in Rendzinas on slopes is more stable compared to Rendzinas on flat positions as a consequence of reduced wetting. South (also, southeast and southwest) and north (northwest and northeast) slopes do not differ in organic matter composition.

Lower average HA content is observed at the wettest west and the driest east and south east regions of Serbia. The wettest west regions have the highest FA content, and the highest content of humins is found in east and south east regions. Average HA/FA ratio in total Rendzinas is as follows: Srem > central > southeastern > eastern > western, and for calcareous Rendzinas: central > Srem > southeastern > western > eastern. Significantly higher HA/FA ratio is found in southeast compared to west, and in central compared to east Serbia. Average composition of fulvo acids is similar in all regions, while humic acids in the eastern region has increased HA2 content, and decreased HA3 content, compared to other regions.

Average temperature in all regions is similar, except on Pester plateau (region of western Serbia) which is cooler. Differences in average annual precipitation are more pronounced among regions, and they are as follows: western > central > Srem > eastern > south-eastern region. Differences of climate influenced vegetation (the scarcest in the driest south-eastern region), while differences in organic matter composition do not completely follow differences in humidity of the regions. Still, western region, the most humid one, has the least favourable HA/FA ratio, whilst the driest south-eastern and eastern regions have the highest content of humin, the most stable portion of humus.

According to the literature [21], it is assumed that possible increase in temperatures due to global warming will change pedogenetic characteristics of organic matter. We can presume that climate change in some regions of Serbia (8, 9) will increase differences in organic matter composition of Rendzina soils in the future.

CONCLUSIONS

Difference in temperature and water regimes in Rendzinas on various altitudes in Serbia (151-1210 m), are not pronounced enough to have a significant influence on organic matter composition.

Landform has significant influence on organic matter composition in Rendzinas of Serbia. Average HA content is higher on slopes and FA content is higher on flat positions, which could be caused by less wet soil on slopes. Exposition had no significant impact on organic matter compositions in Rendzinas of Serbia.

Differences in humidity of studied regions of Serbia are more pronounced than differences in temperatures. Differences in organic matter composition between regions are small and do not follow pattern of humidity. Humus of Rendzina from western region has averagely less favourable HA/FA ratio, whilst the driest south-eastern and eastern region have the highest content of humin.

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