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INFLUENCE OF ENVIRONMENTAL CONDITIONS ON CARBON AND NITROGEN CONTENT IN SERBIAN RENDZINA SOILS

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ABSTRACT

Organic matter in Serbian Rendzina soils dependence on altitude and geographic regions was investigated. There was no regular dynamics of carbon and nitrogen content nor in C/N ratio, probably because of slight climatic variation among altitudes and regions, thus negligible differences in vegetation, organic litter and decomposition dynamics. Predicted climatic changes, uneven for regions, will exert a complex influence on soil C and N storage. These results should be used as a base for future monitoring of C and N content in Serbian Rendzina soils and their dependence on climate.

Keywords: *altitude, temperature, precipitation, climate change*

INTRODUCTION

Soil organic matter is a significant carbon reservoir on the Earth's surface and plays a fundamental role in ecosystem functioning [1]. Small changes of soil organic matter may influence long-term ecosystem sustainability, the global carbon budget and the atmospheric CO_2 concentration [2]. The following factors have a significant impact on the storage of carbon in different ecosystem are: climate, altitude, topography, land cover or vegetation cover, soil texture, land use change, salinity, sodicity, soil erosion, litter decomposition and microbial population [3]. Temperature and moisture are two critical environmental factors influencing soil carbon storage [4]. Altitude is often employed to study the effects of climatic variables on soil organic matter dynamics [5]. Generally, temperature decreases and precipitation increases with increasing altitude. Changes in climate, along altitudinal gradients, influence the composition and productivity of vegetation and microbial activity, consequently affecting the quantity and turnover of soil organic matter [6]. Impact of climate has become more important due to current climatic changes, as the Intergovernmental Panel on Climate Change reported a global linear increase of 0.56–0.92 ^{o}C during 1906–2005 [7]. A high heat or warmer temperature may reduce the storage of recalcitrant carbon and ultimately affect the storage of soil organic carbon in various ecosystems [8]. In Serbia, the average air temperature in last 30 years was rising by 4,54^{o}C /100 years rate. There are regions with negative (only southeast Serbia) and positive trends (north Serbia, Loznica area, Belgrade area, Negotinska Krajina) in annual air temperature. Negative trends in annual precipitation are prominent in east of the country, maximal in Negotinska Krajina, more than 30% of 50 year average. Area around Negotinska krajina and Velika and Juzna Morava, together with broad area around Vranje have slight tendency toward precipitation reduction, up to 20%. Positive trend in annual precipitation is present in southwest and west (Pester and Zlatibor, up to 40%) and north of Serbia [9]. Annual temperature in Serbia will rise for 4^{o}C by the end of this century, according to some estimations [10,11], and some regions will have up to 20% less precipitation during summer.

According to Skoric et al. [12], Rendzinas are soils with mollic A horizon which gradually transits to loose calcareous C horizon. Rendzinas are common in all parts of Serbia, Figure 1, on various calcareous rocks (other than indurated limestone and dolomite), altitudes and relief forms, under various forest and grass communities, or are turned into arable land. Heretofore, studies have shown that carbon and nitrogen content in Rendzinas in Serbia is influenced by processes of carbonate and base leaching and changes in land use, i.e. conversion of forests into grassland and arable land [13]. Since Rendzinas are widespread in all parts of Serbia, on various altitudes, this study shows influence of altitude, precipitation and temperature on carbon and nitrogen content in Rendzinas in Serbia. Our research should indicate soil organic carbon and nitrogen sensitivity to climate in the past, and also, considering predicted increase in climatic variations among regions in Serbia by the end of this century [10,11], it should help to predict soil organic matter content and quality dynamics.

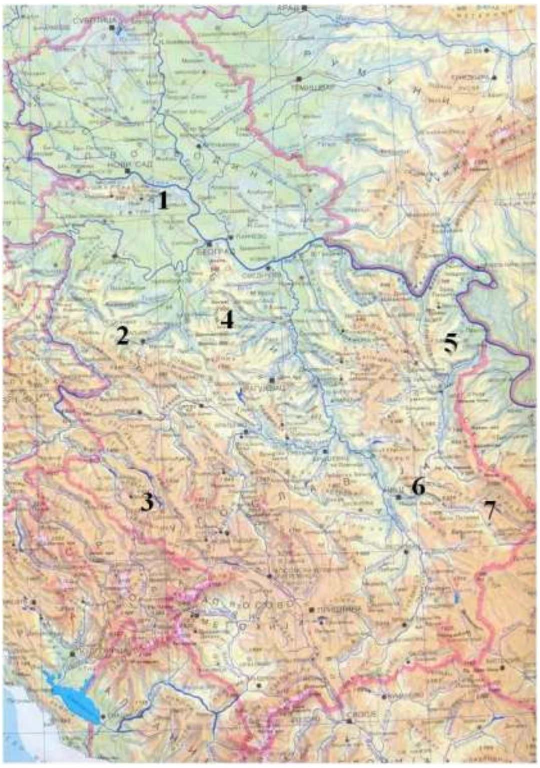

Figure 1 Study area with weather bureaus in regions of Serbia: Srem 1-Rimski Sancevi; West 2-Valjevo; Southwest 3-Sjenica; Central 4-Belgrade; East 5-Negotin; Southeast 6-Nis and 7-Pirot.

MATERIALS AND METHODS

Content of carbon and nitrogen was measured in 24 soil profiles of calcareous Rendzina (9 under forest, 9 under grass and 6 of arable land) and 9 soil profiles of decarbonated Rendzina (4 under forest, 3 under grass and 2 arable land). One or two disturbed soil samples were taken from each A horizon, 14-30 cm deep. Particle size distribution was determined by pipette method, disaggregation with sodium-pyrophosphate [14]; pH in water potentiometrically (soil/water ratio 1:2.5); total C by dihromate method; total N by micro-Kjeldahl method; C/N ratio by calculation; smaller C/N ratio denotes preferable amount of nitrogen in soil organic matter [15].

Carbon and nitrogen content was shown for Rendzinas grouped by regions and altitudes, separately for calcareous and decarbonated Rendzinas, and under forest, under grass and arable land. Table 1 shows two ways of data arrangement: five regions and three altitudes. The most important environmental conditions are shown for each group of Rendzinas: altitude, parent material, average annual precipitation and temperatures, land use (forest, grassland, arable land) and basic characteristics of vegetation. Figure 1 shows study regions - weather bureaus used for collecting data on climate (average for period 1971-2010 [16]).

Table 1 General environmental parameters

Group	Altitude (m)	Parent material[b]	No[a]	Precipitation (mm)	Tempera-ture (°C)	Land use Vegetation
REGION						
Srem	187-190	sm	1	656.2	11.36	G[c] abundant
West and southwest	151-1210	m. sl	2, 3	814.9-768.4	11.37-6.62	F[d], G abundant; A[e]
Central	240-290	sl	4	698.2	11.70	F[d], G - abundant; A
East	199-250	sl	5	652.6	11.71	G - abundant; F[d], A
Southeast	335-720	sm. cm. ml. sl. cg	6, 7	592.9-605.8	11.39	F[f], A, G scarce
ALTITUDE						
Calcareous	<200	sl. sm	1, 5	656.2-652.6	11.36-11.71	G, F, A
	200-600	ml. sl. m. sm. cm	2, 4, 5, 6, 7	605.8-814.9	11.39-11.37	F, A, G
	>700	ml. sl	3, 6, 7	592.9-768.4	6.62-11.39	F, G, A
Decarbo-nated	<200	sl	5	652.6	11.71	F
	200-400	sl	4, 5	652.6-698.2	11.71	G, A, F
	400-600	sl. cg	2, 7	605.8-814.9	11.37	F, G

[a] numbers of weather bureaus shown on Figure 1;
[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] lush forest, dense canopy; species: Turkey oak (*Quercus cerris* L., *Quercus pubescens* Willd.), less often Hawthorn (*Crataegus spp*.), Hornbeam (*Carpinus spp*.) and Ash (*Fraxinus spp.*); in park in Oplenac Black pine (*Pinus nigra* Arnold);
[e] on all arable land rotation of small grains or maize;
[f] degraded forest and coppice: Turkey oak, Hawthorn and European wild pear (*Pyrus pyraster* Burgsd.).

RESULTS AND DISCUSSION

Table 2 shows that average clay content and pH values do not differ significantly among calcareous Rendzinas on various altitudes, while carbonate content increases with increased altitude. Decarbonated Rendzinas show similar clay content and pH values on various altitudes. Calcareous and decarbonated Rendzinas of various regions showed differences, especially in clay content, carbonate content, while pH values were quite uniform.

In general, soil organic carbon (and N) increases with increasing precipitation, decreasing temperature, and decreasing evapotranspiration/precipitation ratio due to reduced lignin degradation, i.e. slower decomposition rates [4,17,18,19]. But there are also opposite experiences, for instance in India carbon stock in different types of forests on Himalayan mountain regions tended to decrease with increasing altitudes. The characteristic decline in vegetation with increasing altitude results in less accumulation of litter and low input of organic carbon in soils [20].

In Mediterranean high mountain soils C and N decreased and C/N ratio increased with increasing altitude, indicated an altitudinal variation in the quality of soil organic matter [6]. Table 3 shows there is inconsistent dynamics of carbon and nitrogen content, neither of C/N ratio with altitude increase, neither in calcareous nor in decarbonated Rendzinas. For surveyed Rendzinas in Serbia altitude had no significant influence on C and N content, most probably because there is no notably difference in climate of three altitude groups, Table 1, so there are no significant differences in vegetation, organic litter and decomposition dynamics.

Table 2 General soil properties in A horizon of Rendzinas groped by altitudes and regions

Rendzina	Group	n	clay (%) mean	clay (%) std.dev.	$CaCO_3$ (%) mean	$CaCO_3$ (%) std.dev.	pH in H_2O mean	pH in H_2O std.dev.
	ALTITUDE (m)							
Calcareous	<200	13	31.78	10.35	7.85	5.87	7.67	0.16
	200-600	16	30.26	9.64	9.55	11.06	7.67	0.12
	>700	4	36.56	8.98	11.47	9.10	7.69	0.11
Decarbonated	<200	1	28.96	-	0	-	7.15	-
	200-400	5	31.72	3.44	0	-	7.17	0.36
	400-600	5	33.57	8.90	0	-	6.71	0.56
	REGION							
Calcareous	Srem	2	8.94	1.27	18.25	4.91	7.87	0.25
	West	4	24.92	10.11	18.34	17. 90	7.68	0.09
	Central	2	41.26	4.95	5.35	4.95	7.63	0.20
	East	15	35.51	2.48	4.78	3.71	7.63	0.12
	Southeast	10	31.08	10.56	10.85	7. 40	7.70	0.13
Decarbonated	Srem	0	-	-	-	-	-	-
	West	1	39.36	-	0	-	6.99	-
	Central	2	32.18	2.35	0	-	6.85	0.19
	East	4	30.80	3. 90	0	-	7.00	0.23
	Southeast	2	24.04	3.62	0	-	6.39	0.85

Table 3 Carbon and nitrogen content in A horizons of Rendzina soils grouped by altitude

Rendzina	Altitude (m)	n	C (%) mean	C (%) std.dev.	N (%) mean	N (%) std.dev.	C/N mean	C/N std.dev.
Calcareous								
total	<200	13	3.56	1.12	0.364	0.10	9.76	0.66
	200-600	16	3.04	1.51	0.295	0.13	9.86	2.71
	>700	4	2.99	2.12	0.305	0.20	9.36	1.07
forest	<200	4	4.56	1.45	0.435	0.11	10.37	0.71
	200-600	6	4.35	0.59	0.409	0.10	11.13	2.77
	>700	1	5.04	-	0.464	-	10.86	-
grassland	<200	9	3.12	0.61	0.332	0.08	9.48	0.45
	200-600	3	3.42	2.01	0.323	0.14	8.49	4.51
	>700	1	4.60	-	0.489	-	9.41	-
arable land	200-600	7	1.76	0.64	0.185	0.05	9.36	1.51
	>700	2	1.15	0.09	0.134	0.01	8.58	0.01
Decarbonated								
total	<200	1	3.30	-	0.300	-	11.00	-
	200-400	5	2.66	1.30	0.241	0.11	10.95	1.64
	400-600	5	2.84	1.44	0.261	0.13	10.98	1.73
forest	<200	1	3.30	-	0.300	-	11.00	-
	200-400	1	4.56	-	0.425	-	10.73	-
	400-600	2	3.57	2.08	0.315	0.20	11.63	0.92
grassland	200-400	2	2.32	1.50	0.206	0.09	10.67	2.63
	400-600	1	2.12	-	0.262	-	8.09	-
arable land	200-400	2	2.06	0.06	0.184	0.03	11.34	1.83

Table 4 shows similar C and N content, and also similar C/N ratio in most regions in Serbia. Greatest content of C and N is present in calcareous Rendzinas in western and eastern Serbia. Carbon to nitrogen ratio is various. Among calcareous Rendzinas under forest C/N ratio is the lowest in west Serbia, and among Rendzinas under grass and arrable it is lowest in southeast Serbia. Decarbonated Rendzinas have greatest content of C and N in southeast and central Serbia, while the amount of nitrogen in humus is the greatest in west and central Serbia. Similar inconsistent results have been reported in other regions [21,22].

These inconsistencies make region-specific assessment of the quantitative relationship of soil C and N storage with climate difficult [23]. As shown in Table 1, temperatures in all regions are very similar, around 11ºC (except southwest Serbia (Sjenica) around 6 ºC, with only one soil profile). Precipitation are scarcest in southeast and most abundant in west Serbia, which causes scarce vegetation in southeast and lush vegetation in the west. Nevertheless, these differences do not cause significant differences of organic matter content nor in nitrogen content in Serbian Rendzina soils. Differences in clay content of calcareous and decarbonated Rendzinas are not correlated to carbon and nitrogen content

Table 4 Carbon and nitrogen content in A horizons of Rendzina soils grouped by regions

Rendzina	Region	C (%)			N (%)		C/N	
		n	*average*	*SD*	*average*	*SD*	*average*	*SD*
Calcareous								
total	Srem	2	3.82	0.69	0.431	0.11	8.95	0.68
	West	4	3.90	1.37	0.414	0.14	9.35	0.59
	Central	2	3.50	0.59	0.238	0.00	14.52	2.86
	East	15	3.31	1.43	0.326	0.12	9.99	0.75
	Southeast	10	2.70	1.65	0.278	0.14	9.30	1.20
forest	West	2	4.57	0.11	0.481	0.03	9.53	0.90
	Central	1	3.92	-	0.237	-	16.54	-
	East	4	4.56	1.45	0.435	0.11	10.37	0.71
	Southeast	4	4.51	0.77	0.429	0.09	10.52	0.79
grassland	Srem	2	3.82	0.69	0.431	0.11	8.95	0.68
	West	1	4.60	-	0.489	-	9.41	-
	East	9	3.19	1.03	0.318	0.07	9.95	0.79
	Southeast	1	1.97	-	0.235	-	8.38	-
arable land	West	1	1.84	-	0.206	-	8.93	-
	Central	2	1.37	0.03	0.146	0.00	9.38	0.08
	East	1	3.08	-	0.240	-	12.50	-
	Southeast	5	1.39	0.35	0.166	0.05	8.50	0.55
Decarbonated								
total	West	1	2.12	-	0.262	-	8.09	-
	Central	2	2.91	2.33	0.284	0.20	9.77	1.36
	East	4	2.70	0.74	0.235	0.06	11.55	1.25
	Southeast	2	3.57	2.08	0.315	0.20	11.63	0.92
forest	Central	1	4.56	-	0.425	-	10.73	
	East	1	3.30	-	0.300	-	11.00	-
	Southeast	2	3.57	2.08	0.315	0.20	11.63	0.92
grassland	West	1	2.12	-	0.262	-	8.09	-
	Central	1	1.26	-	0.143	-	8.81	-
	East	1	3.38	-	0.270	-	12.53	-
arable land	East	2	2.06	0.05	0.184	0.03	11.34	1.83

If regional trend of climate change should continue [9], differences between some regions in Serbia would become more pronounced (temperature rise and reduced precipitation in Negotinska krajina, decrease of temperature and precipitation in southeast and increase of temperature and precipitation in west of the country). Climate changes predicted for the end of this century [10,11] will exert a complex influence on soil C and N storage in certain regions. Data shown in this paper should be used as a base for future monitoring of carbon and nitrogen content dynamics in Rendzina soils in Serbia, and their dependence on climate change.

CONCLUSIONS

There is no pattern in dynamics of carbon and nitrogen content nor in C/N ratio in A horizon of Serbian Rendzina soils with altitude increase, nor within certain regions. This inconsistent dynamics probably comes from small differences in climate of various altitudes and regions, since there is no difference in vegetation, organic litter and decomposition dynamics. Predicted climate change, uneven for regions, will probably exert a complex influence on soil C and N storage. Data shown in this paper should be used as a base for future monitoring of carbon and nitrogen content dynamics in Rendzina soils in Serbia, and their dependence on climate change.

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