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Original Research

Soil Organic Carbon in Serbian Mountain Soils: Effects of Land Use and Altitude

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Abstract

The aim of our research was to investigate the concentration and stock of organic carbon (SOC) in soils of Golija Mountain, Serbia, under different land uses (grassland, forest, and arable land) at different altitudes (1,500 m, 1,000 m, and 500 m) and at two soil depths (0-10 cm and 10-20 cm), and to assess resilience of soil organic matter to decomposition under each of the ecosystems by measuring the amount of SOC and soil respiration rate. The results show the highest SOC stock under forest and lowest under grass, a decreasing trend in SOC from higher to lower altitudes, the lowest cumulative soil respiration under forest and the highest under grass. This study demonstrates that the land use system and altitude are important factors affecting SOC.

Keywords: soil organic carbon, soil respiration, land use, altitude, soil degradation

Introduction

Soil organic carbon (SOC), a major constituent of soil organic matter (SOM), is a product of the decomposition of plant residues, roots, and living and dead soil organisms [1]. The ratio of SOM/SOC lies between 1.4 and 3.3 in most soils [2, 3], and SOM is usually estimated by the detection of SOC concentration through a conversion factor of 1.724 [4]. The importance of SOM for sustainable fertility and productivity of soils is well known [5, 6]. Besides, SOM is the largest pool of terrestrial SOC [7, 8]. However, SOM can act both as a sink or a source of C in response to climate, land use changes, and to rising atmospheric CO_2 levels [9].

Loss of SOC leads to soil degradation and to emission of CO_2 from the soil to the atmosphere. Carbon dioxide is one of the greenhouse gases (GHGs) whose increase in the atmosphere is now recognized as contributing to climate change [10]. However, sequestering CO_2 in soil by proper soil management, along with decreasing the emission of GHGs into the atmosphere, is one of the leading aspects of mitigating global warming and protecting or increasing existing soil C stock [7].

Resilience of SOC to decomposition depends on a large number of physical, chemical, biological, microbiological, and biochemical properties [11, 12] that vary under different ecosystems [13, 14]. Many investigations have shown that forest ecosystems are much more resistant to decomposition of SOC than arable land or grassland [14, 15]. However, several studies show that conifer litter contains more components that are difficult to decompose than broadleaf litter, resulting in litter accumulation on the forest floor and the formation of acid compounds [15, 16]. Grassland generally has higher SOC levels than arable land [17]. However, grazing activity increases respiration rate compared to undisturbed soils, reflecting an accelerated

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mineralization of SOC characterized, in fact, by the disturbed sites that could therefore be prone to a loss of OM in the long term, with relevant negative consequences (loss of structure, lower water retention, loss of biological fertility, and erosion) [18].

Altitude is often included in studies of the effects of climatic variables on SOM dynamics [19, 20]. Generally, temperature is decreased and precipitation increased with increasing altitude [21]. The changes in climate along altitudinal gradients influence the composition and productivity of vegetation and, consequently, affect the quantity and turnover of SOM [19, 22, 23]. The surface SOM concentration correlated negatively with annual mean temperature and correlated positively with annual mean precipitation and altitude [24]. Decreasing temperature with altitude has been shown to limit SOC turnover in forest soils, leading to enhanced SOC storage [25]. Altitude also influences SOM by affecting soil water balance, soil erosion, and geologic deposition processes [26].

Golija Mountain in southwestern Serbia, belongs to the inner zone of the Dinaric mountain system. Golija Nature Park is a protected area, one of only a few mountainous regions of preserved nature. Floral biodiversity of Golija consists of about 900 plant taxa, of which 728 are identified vascular plant species, 40 moss species, and 117 algal species and varieties [27]. However, the local population has been clearing forests for centuries, transforming forest into large pastures, meadows, and fields. Moreover, land use change from forest or grassland to arable land is still practiced in the region. However, to ensure sustainable land management and to protect the land from degradation, it is necessary to achieve and to maintain SOC at a satisfactory level. To estimate the reserves of SOC and to prevent its further losses, it is necessary to collect the data and to find out the relationship between SOC stock and the type of soil, topography, land use, and climate.

In Serbia in general, as well as for Golija Mountain, there is a lack of data regarding SOC. Also, according to Kyoto protocol, there is a need to estimate the current SOC concentrations and stocks stratified by land use, management, soil types, and climate region. Therefore, the aim of this research was to investigate:

i) the concentration and stock of SOC in soils of Golija Mountain under different land uses (grassland, forest, and arable land) at different altitudes (1,500 m, 1,000 m, 500 m) and at two soil depths (0-10 cm and 10-20 cm)
ii) to assess resilience of SOM to decomposition, under different land uses, altitudes, and depths, by measurement of soil respiration in an incubation experiment

Material and Methods

Soil Sampling and Analysis

The study area is located on Golija Mountain, which varies in altitude from 415 m to 1,833 m (Jankov Kamen), from hills to subalpine belt, in a climatogenic zone of forest vegetation. The climate is of the humid temperate continental type with average annual precipitation of 1,092 mm and average temperature of 7.4ºC (Republic Hydrometeorological Service of Serbia).

In October 2008, soils were sampled from three different sites at different altitudes (site 1: 1,500 m, site 2: 1,000 m, site 3: 500 m). For each site three soil samples were collected about 200 cm from each other under each of the three adjacent ecosystems:

1) grassland (established approximately 100 years ago)
2) forest
3) arable land – raspberry field (established 10 to 30 years ago) (Table 1)

Samples were taken at two soil depths: 0-10 and 10-20 cm. Soil samples, 54 in total, were air-dried and manually sieved through a 2-mm sieve for chemical and texture analysis. Bulk density (BD) was determined by Kopecki cylinders; particle size distribution by the pipette method [28]; pH value in a soil suspension with water (ratio 1:2.5; w/v) was determined potentiometrically with a pH-meter. Total N was determined using Kjeldhal's method modified by Bremmer and Mulvaney [29], bioavailable phosphorus and potassium were extracted with AL solution (0.1 M ammonium lactate and 0.4 M acetic acid, pH 3.75) at a soil to solution ratio of 1:20 (w/v), following the method described by Enger et al. [30], and SOC was determined by oxidation with K_2CrO_7 in an acid medium followed with evaluation of the excess dichromate with $(NH_4)_2Fe(SO_4)_2$ [31].

Soil organic C content for the soil depths of 0-10 and 10-20 cm was calculated for each of the ecosystems, as follows:

$$\text{SOC (Mg·ha}^{-1}\text{)} = \text{(\% SOC/100)} \times \text{soil mass (Mg·ha}^{-1}\text{)} \quad (1)$$

...where soil mass (Mg·ha^{-1}) = depth (m) × bulk density (Mg·m^{-3}) × 10,000 $\text{m}^2\text{·ha}^{-1}$.

Incubation Procedure

Potentially mineralizable C (C_0) provides a good index of the most active pools of organic matter. To determine C_0, we used a standard laboratory incubation technique. Soil samples were air-dried and 50 g of soil subsample was placed into a cup, brought up to field capacity, and incubated in a 1,000 ml plastic jar at a constant 28ºC temperature in the dark for 28 days. The jar also contained a vial of 1.5 N NaOH to serve as a CO_2 trap for the estimation of CO_2 respired during the incubation period (potentially mineralizable C) and approximately 10 ml of distillated water on the bottom for maintaining a saturated atmosphere. CO_2 produced during incubation was measured daily during the first week and then weekly. The CO_2 trap was titrated with 1.0 N HCl and C mineralization was estimated following the exponential model: $C_t = C_0\ (1 - e^{-kt})$, where C_t is the cumulated mineralized C during t days, k is mineralization rate constant, and C_0 is the potentially mineralizable C [32].

Table 1. Land use, vegetation type, altitude, latitude, and longitude for the investigated soils.

Site	Altitude (m)	Land use	Vegetation type	Soil texture (0-20 cm)	Latitude, longitude
1	1,450	Grassland	*Festuca pratensis, F. rubra, F. valesiava, Anthoxanthum odoratum*	Loamy sand	N 43º 23’ 42.0” E 20º 27' 40.32"
		Forest	*Picea abies*	Sandy loam	N 43º 15’ 13” E 020º 9’ 27”
		Arable land	*Rubus idaeus*	Sandy loam	N 43º 13' 7.89" E 20º 10' 18.55"
2	1,020	Grassland	*Festuca pratensis, F. rubra, F. valesiava, Anthoxanthum odoratum*	Sandy loam	N 43º 16' 19.13" E 20º 9' 28.69"
		Forest	*Fagus moesiaca*	Sandy loam	N 43º 16' 19.02" E 20º 9' 25.20"
		Arable land	*Rubus idaeus*	Sandy loam	N 43º 16' 18.91" E 20º 9' 28.80"
3	500	Grassland	*Festuca pratensis, F. rubra, F. valesiava, Anthoxanthum odoratum*	Sandy loam	N 43º 17' 50.96" E 20º 8' 33.11"
		Forest	*Fagus moesiaca*	Sandy loam	N 43º 17' 51.28" E 20º 8' 33.83"
		Arable land	*Rubus idaeus*	Sandy loam	N 43º 17' 51.75" E 20º 8' 33.32"

Table 2. Soil physical and chemical properties affected by land use, altitude, and soil depth (means ± SD).

	n	BD (Mg·m^{-3})	pH (H_2O 1:2.5)	SOC (g·kg^{-1})	N_{tot} (g·kg^{-1})	C/N	AL-P_2O_5 (mg 100^{-1} g)	AL-K_2O (mg 100^{-1} g)
Land use								
Grassland	18	1.31±0.11 a	6.31±0.70 a	39.5±3.8 b	3.36±1.11 b	11.4±2.17 b	4.07±6.80 b	16.8±9.65 c
Forest	18	1.28±0.05 b	6.03±1.29 b	57.9 ±5.5 a	3.57±1.44 a	15.6±3.45 a	4.24±3.22 b	18.4±7.23 b
Arable land	18	1.33±0.04 a	5.37±1.01 c	40.8 ±2.4 b	3.33±0.08 b	11.9±2.32 b	29.1±25.2 a	44.6±26.9 a
Sites								
1	18	1.33± 0.06 a	5.10±0.45 c	52.7 ± 5.8a	4.02±1.47 a	12.9±2.92 b	3.58±1.76 c	22.7±7.25 b
2	18	1.27±0.06 b	5.37±0.37 b	46.2 ±4.4 b	2.98±1.02 c	15.4±4.02 a	10.2±12.9 b	19.5±6.25 c
3	18	1.36± 0.08 a	6.32±1.47 a	39.4 ±2.2 c	3.35±1.03 bc	11.8±1.92 c	18.0±30.1 a	32.16±32.4 a
Soil depth								
0-10 cm	27	1.32±0.08 a	5.85±1.02 b	56.8 ±3.4 a	4.10±1.17 a	13.4±3.62 a	16.2±23.4 a	31.8±24.9 a
10-20 cm	27	1.29±0.07 b	5.95±1.16 a	35.4 ±2.6 b	2.74±0.54 b	12.5±2.82 b	8.72±12.8 b	21.5±15.1 b

Within the same column and factor (land use, site, or soil depth), values followed by different letters are significant at $P<0.05$.

Statistical Analysis

Statistical analysis was carried out using Statistica 8 (StatSoft Inc., OK, USA). Factorial ANOVA was used to assess the effects of ecosystem type, altitude, soil depth, and their interactions with SOC. Fisher's LSD procedure was used for multiple comparisons of mean physical and chemical properties of the soil depths (0-10 and 10-20 cm) among the ecosystems (grassland, forest and arable land) and different sites at $p<0.05$ level. Pearson's correlation coefficients (r) were determined for the correlation matrix of all the variables (bulk density, SOC, plant-available phosphorus and potassium, pH, total C/N ratio, and basal and cumulative respiration).

Results

Soil Physical and Chemical Properties Affected by Land Use, Altitude, and Soil Depth

Land use. Bulk density and the chemical properties of the soils have been modified by land use (Table 2). Bulk density was greater under grassland and arable land than forest, as opposed to the concentration of SOC and total N in soil, and C/N ratio. Soil pH was increased in the order: arable land > forest > grassland. Plant available AL-P_2O_5 and AL-K_2O were highest under arable land as a result of fertilization of raspberries; there were no differences in AL-P_2O_5 under grassland and forest, while AL-K_2O was higher under forested soils than under grassland.

Altitude. Bulk density was greater under sites 1 (1,500 m) and 3 (500 m), than under 2 (1,000 m). There was an increasing trend in pH-values going from the higher to lower sites ($5.10\pm0.45<5.37\pm0.37<6.32\pm1.47$). The opposite trend was found for SOC; concentrations were in the following order $52.7\pm5.8>46.2\pm4.4>39.4\pm2.2$ g·kg^{-1} soil (Sites 1-3 respectively). Also, total N was greater at the highest altitude than at the lower ones. Plant available AL-P_2O_5 and AL-K_2O were greatest in soils at the lowest altitude. The total concentration of N was greatest at the highest site, but there were no differences between sites 2 and 3. C/N ratio was recorded in the following order: site 2>site 1>site 3.

Soil depth. Except for pH-value, all other investigated soil indices were greater in the topsoil than in subsoil. Bulk density was also higher in the topsoil than in subsoil. Higher values of total N and C/N ratio were found in the 0-10 cm layer than in the 10-20 cm layer.

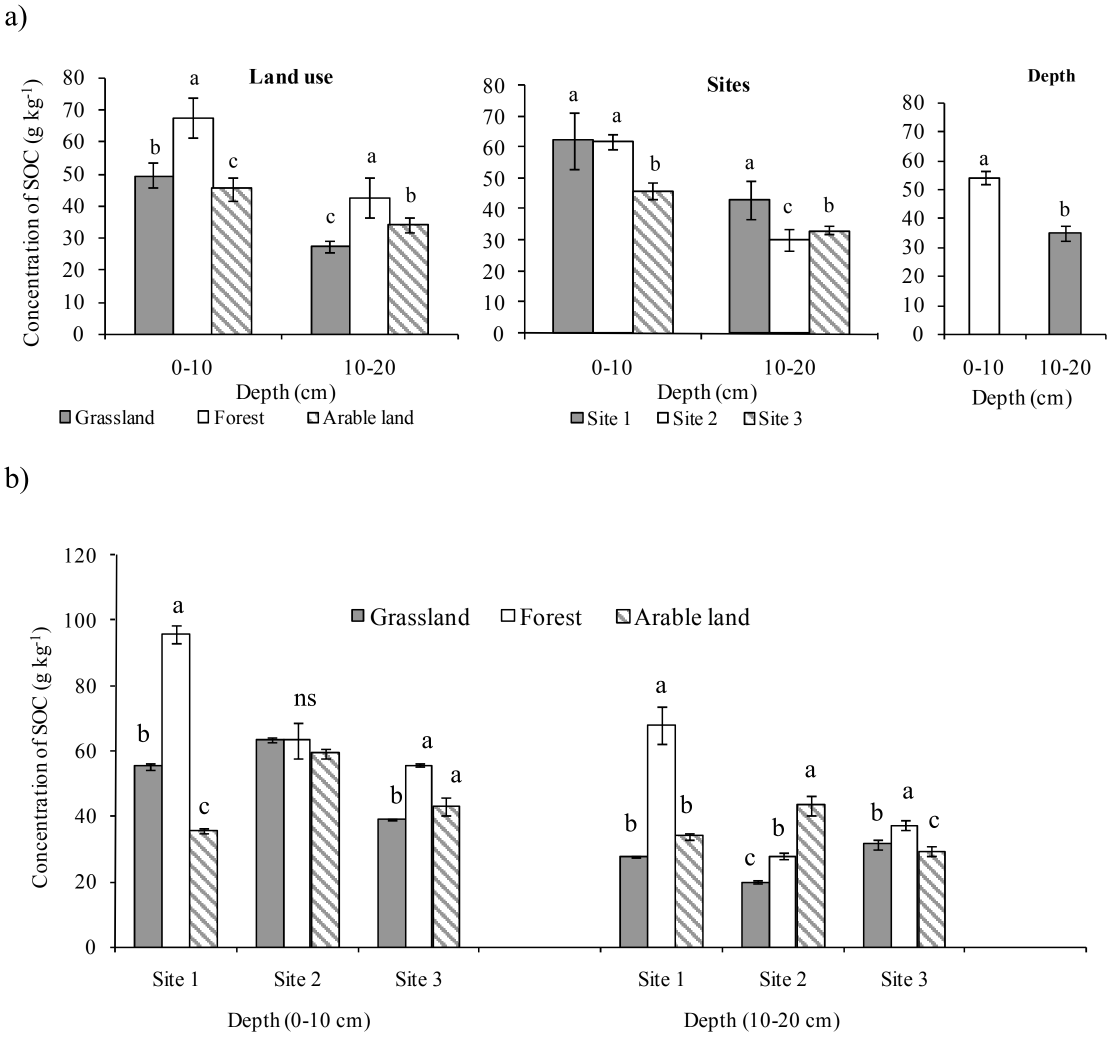

Fig. 1. Soil organic carbon concentration (g·kg^{-1}) affected by land use, altitude, and soil depth (means ± SD). Within the same factor (land use, site, or soil depth), values followed by different letters are significant at $P<0.05$.
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Soil Organic Carbon Concentration Affected by Land Use, Altitude, and Soil Depth

Land use. In both soil depths (0-10 and 10-20 cm), soils under forest had a significantly higher level of SOC than soils under arable land or grass (Fig. 1a). A higher concentration of SOC under grass than under arable land was found in 0-10 cm soil depth, while in 10-20 cm depth an opposite trend was observed.

Altitude. Soil organic C concentration at soil depth 0-10 cm and 0-20 cm (data not shown) decreased going from the higher altitudes to the lower ones, but at 0-10 cm depth there were no differences in SOC concentration at sites 1 (1,500 m) and 2 (1,000 m). At depths of 10-20 cm SOC concentration was in the order: site 1>site 3>site 2.

Soil depth. Higher contents of SOC were found in the 0-10 cm layer than in the 10-20 cm layer.

Soil organic C concentration data for each site and soil depth is shown in Fig. 1b.

Soil Organic Carbon Stock Affected by Land Use, Altitude, and Soil Depth

Land use. In the soil layer of 0-20 cm, the SOC stock was in the order: forest > arable land > grassland (Fig. 2a). However, there were some differences in SOC storage between soil depths caused by differences in the length of the root systems of different species. In the soil depth 0-10 cm SOC stock was in the order forest > grassland > arable land, while in the 10-20 cm depth, SOC stock was in the order forest > arable land > grassland, due to differences in root depth of forest and grass plants.

Altitude. Soil SOC stock along the slope of the mountain followed the same rule as for SOC concentration, exhibiting a decreasing trend from the top to site 3 (500 m). At 0-10 cm soil depth cm a lower SOC stock was observed at site 3, but there were no differences in SOC stock between sites 1 and 2. At the 10-20 cm depth SOC stock was in the order: site 1 > site 3 > site 2.

Soil depth. Organic carbon stock was higher in the 0-10 cm layer than in 10-20 cm.

Soil organic C stock data for each site and soil depth is shown in Fig. 2b.

Soil Respiration Affected by Land Use, Altitude and Soil Depth

Land use. Cumulative soil respiration was in the order: grassland > arable land > forest, while basal soil respiration was greater in arable land than in grassland and forest

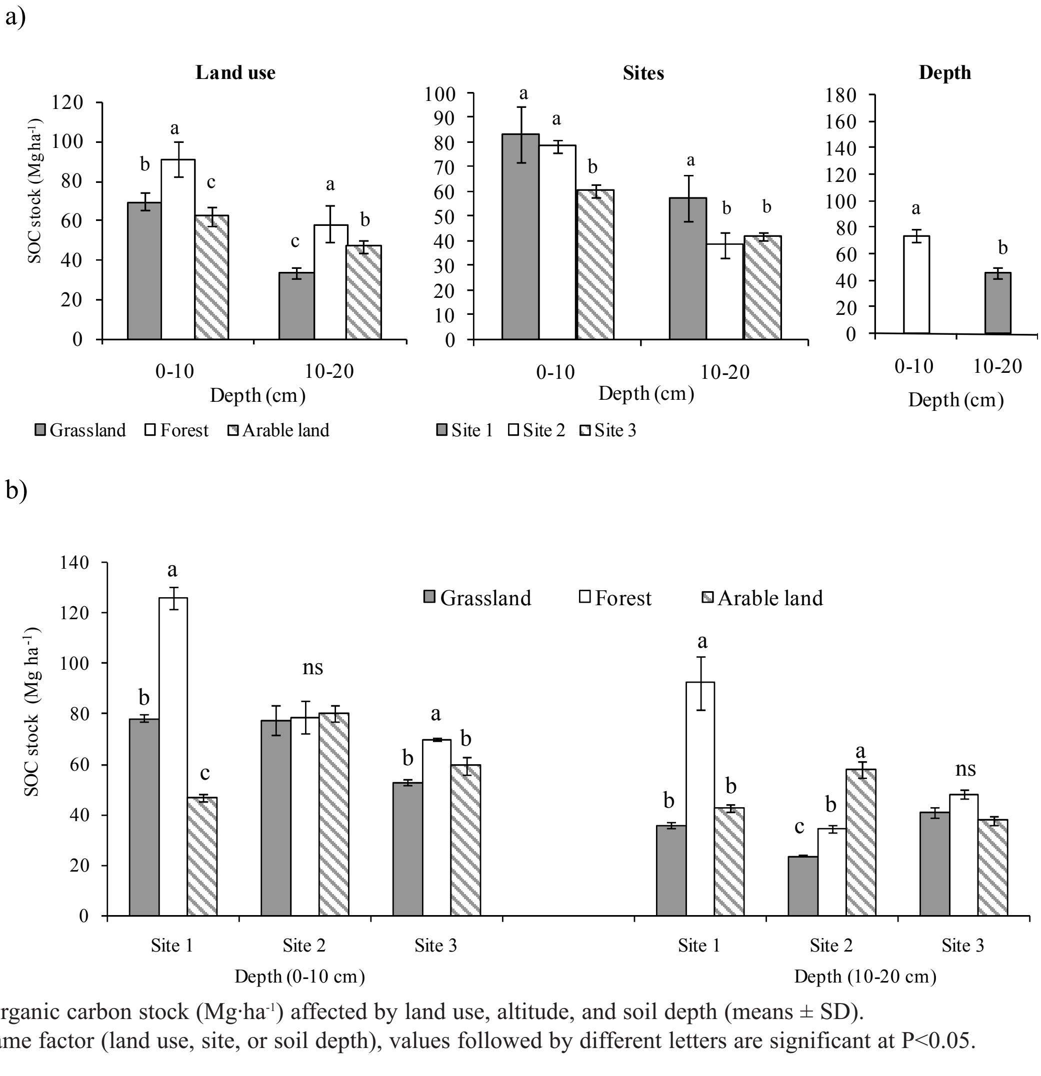

Fig. 2. Soil organic carbon stock (Mg·ha^{-1}) affected by land use, altitude, and soil depth (means ± SD).
Within the same factor (land use, site, or soil depth), values followed by different letters are significant at $P<0.05$.

Table 3. Soil organic carbon parameters affected by land use, altitude, and soil depth (means ± SD).

	n	SOC ($g \cdot kg^{-1}$ soil)	CO_2-C_{basal} ($\mu g \cdot g^{-1}$ soil)	CO_2-$C_{cumulative}$ ($\mu g \cdot g^{-1}$ soil)	C_0 ($\mu g \cdot g^{-1}$ soil)	*k* ($days^{-1}$)
Land use						
Grassland	24	39.5±3.8 b	19.1±2.8 b	268±11.1 a	288±19.1	0.105±0.02
Forest	24	57.9 ±5.5 a	19.4±2.5 b	230±6.5 c	247±16.2	0.097±0.02
Arable land	24	40.8 ±2.4 b	25.1±2.7 a	253±6.5 b	274±19.0	0.106±0.02
Sites						
1	18	52.7 ± 5.8a	25.7±0.8 a	264±9.5 a	249±14.4	0.110±0.14
2	18	46.2 ±4.4 b	25.8±2.3 a	257±8.6 a	279±17.1	0.109±0.02
3	18	39.4 ±2.2 c	12.3±10.5 b	230±7.3 b	258±20.8	0.095±0.02
Soil depth						
0-10 cm	36	56.8 ±3.4 a	21.5±2.2 a	267±8.2 a	285±18.4	0.105±0.02
10-20 cm	36	35.4 ±2.6 b	20.3±2.3 b	231±4.4 b	255±17.4	0.101±0.02

Within the same column and factor (land use, site, or soil depth), values followed by different letters are significant at $P<0.05$.

(Table 3). Potentially mineralizable carbon (Co) and coefficient *k* (Table 3) pointed out the higher stability of OM in forest soils than in soils under grass or arable land. Grassland soil had the highest cumulative soil respiration, although there were no significant differences in SOC and total N contents between grassland and arable land (Table 2).

Altitudes. The lowest soil respiration was found at site 3 (500 m), but there were no differences between sites 1 (1,500 m) and 2 (1,000 m) (Table 3). Coefficient *k* was in the order: site 1 > site 2 > site 3. However, the distribution of Co values going from the top to the bottom of the slope was different; the highest values of Co were found in soils at sites 2, then 3, and lowest in soils at site 1.

Soil depth. Soil respiration was higher in the soil depth 0-10 cm than in 10-20 cm (Table 3), corresponding to SOC concentration and total N in the depths. Coefficient *k* showed the same behavior.

For SOC concentration data, SOC stock, C/N ratio, basal, and cumulative soil respiration, ANOVA indicated a significant three-way interaction among land use, sites, and soil depth (Table 4).

Correlations

The correlation matrix showed that SOC concentration was correlated positively with N total, C/N ratio, SOC stock, and cumulative respiration (Table 5). The correlation coefficients also revealed positive significant correlation between SOC stock and SOC concentration, N total, and C/N ratio. Cumulative soil respiration showed significant correlation with N total, and basal respiration. Negative correlations were obtained between concentrations of SOC and pH, and also between C/N ratio and pH and bulk density (Table 5).

Discussion

The size of the SOC stock depends on the productivity of vegetation and on the decomposition rate of SOM. The obtained results show that SOC concentration and stock were greater in the soils under forest ecosystems, then under arable land or grassland. Accumulation of SOC under forest can be caused by slower decomposition of SOM under forest ecosystem than under the other ones, which was also noted by Corre et al. [14], Semenov et al. [33], and others. Many authors have reported greater SOC stocks under grassland compared to arable land [34, 35]. However, in our study, a greater concentration and stock of SOC was measured only in the topsoil (0-10 cm soil depth) of grassland than in arable land, but in the layer 10-20 cm an oposite trend was observed, resulting in no significant differences in SOC amount between grassland and arable land in the 0-20 cm layer (data not shown).

Cumulative soil respiration that was lowest in the soils under forest, despite the highest concentration of SOC, indicates high resilience of SOM to decomposition in these soils. That was a result of higher C/N ratio in soils under forest (15.6±3.45) than in soils under other land uses (11.4±2.17 for grassland and 11.9±2.32 for arable land) and probably the result of a different quality of SOM. According to Berg [15], conifer litter contains more components that are difficult to decompose than broadleaf litter, resulting in the accumulation of litter on the forest floor and the formation of acid compounds, which in most cases led to higher accumulation of SOC [36]. In our research, correlation coefficients (Table 5) show that a decrease in pH value of soils leads to accumulation of SOC and, consequently, higher C/N ratio. The similar results were obtained by Motavalli et al. [37], who explained the positive effect of increased soil acidity on accumulation of SOC by

Table 4. Factorial ANOVA table showing degrees of freedom (DF) and *p*-values of SOC concentration ($SOC_{conc.}$), SOC stock, and C/N ratio in the study across land use (grassland, forest, arable land), sites (1, 2, 3), and soil depth (0-10 cm, 10-20 cm).

Factors of interaction	DF	$SOC_{conc.}$	SOC_{stock}	C/N ratio	Basal respiration	Cummulative respiration
		p-values				
Land use	2	<0.0001	<0.0001	<0.0001	0.0111	<0.0001
Site	2	<0.0001	<0.0001	<0.0001	0.0001	<0.0001
Soil depth	1	<0.0001	<0.0001	0.0006	0.0051	<0.0001
Land use × site	4	<0.0001	<0.0001	0.0156	0.0488	0.3347
Site × soil depth	2	<0.0001	0.0001	0.0002	0.1559	0.1010
Land use × soil depth	2	<0.0001	0.0001	0.0269	0.0085	0.0004
Land use × site × soil depth	4	<0.0004	<0.0006	0.0001	<0.0001	0.0196

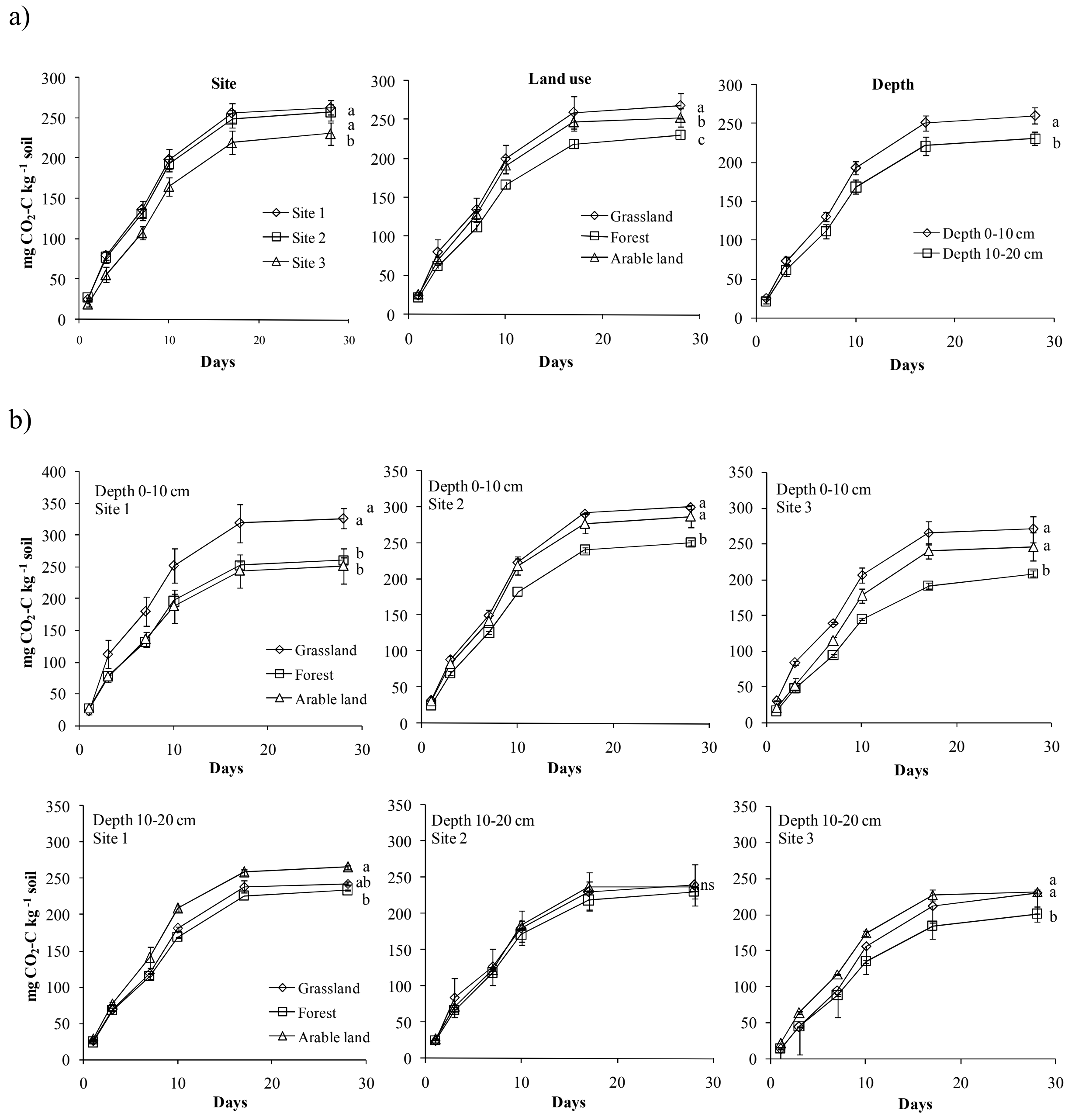

Fig. 3. Cumulative soil respiration (CO_2-C µg·g^{-1} soil) affected by land use, altitude, and soil depth (means ± SD). Within each figure, values followed by different letters are significant at P<0.05.

Table 5. Correlation matrix of soil properties (Pearson's correlation coefficients, r).

Variables	N_{total}	C/N	CO_2-$C_{cum.}$	CO_2-C_{basal}	AL-P_2O_5	AL-K_2O	pH	BD	SOC_{stock}
SOC	0.77**	0.58**	0.32*	ns	0.47*	ns	-0.36**	ns	0.82**
N total		ns	0.55**	ns	0.37*	ns	ns	0.29*	0.50**
C/N			ns	ns	0.39*	ns	-0.36*	-0.37*	0.49**
CO_2-$C_{cum.}$				0.36**	ns	ns	ns	ns	ns
CO_2-C_{basal}					ns	ns	ns	ns	ns
AL-P_2O_5						0.79**	-0.62**	ns	ns
AL-K_2O							-0.62**	ns	ns
pH								ns	ns
BD									ns

*, **, refer to $p \leq 0.05$, $p \leq 0.01$, respectively; ns: not significant at $p \leq 0.05$.

reduced rate of microbial mineralization. In our research, potentially mineralizable carbon (Co) and mineralization rate coefficient *k* (Table 3) also indicated the higher stability of SOM in forest soils than in soils under grass or arable land. Lower coefficient *k* in forest soils than in soils under grass or arable land, pointed out the slower decomposition of organic matter in these soils. Our results are in agreement with Garten et al. [19], who reported a 38% lower average soil respiration rate under forest than under grassland. They could not relate respiration rate with soil moisture, but found 5ºC cooler soil temperatures at the 10-cm depth in forest during the growing season than in grassland, explaining most of the variance in low soil respiration in the forest. Differences in soil respiration due to respiration response to temperature were also confirmed by significantly different temperature sensitivity coefficient Q_{10}, which was lower in soils under forest (2.2) compared to grassland (2.4). However, they did not find significant differences between woodlands and grasslands in long-term (82-week) laboratory incubations of potentially mineralizable soil C and short-term incubations for microbial biomass C.

In our research grassland soils had the highest cumulative soil respiration on average for all sites and depths, although there were no significant differences in SOC and total N contents between grassland and arable land. Similar results were reported by Pulleman and Marinissen [38], who found greater amounts of mineralized SOC in pasture soil than arable soil in a 35-day incubation experiment. The results were explained by strongly humified SOM in arable land against relatively little decomposed, grass-derived SOM. According to Kara and Bolat [39], grassland soils had higher microbial biomass than arable land, which can also increase SOM mineralization. Indirect factors such as increased soil moisture, or mycorrhizal colonization and soil aggregate size may have affected SOC gain and loss as well [40-42]. Besides, compared to the grassland, raspberry as a non-demanding crop in terms of required agronomic practices in the short term, has not caused the degradation of soil, probably due to low intensive tillage of soil and the application of manure. Soil tillage increases soil aeration and exacerbates the rate of mineralization of SOC, which in the long term leads to a decrease in SOC concentration [43, 44]. The results of numerous long-term trials have shown that animal manure application lead to an increase in SOC concentration and stock due to incorporation of organic matter [45, 46].The increase in SOC results in increases in aggregate stability [47].

Organic carbon concentration and SOC stock in soils decreased going from the higher altitudes to the lower. This is in accordance with Sims and Nielsen [48] and Tate [22]. The changes in climate along altitudinal gradients influence the composition and productivity of vegetation and, consequently, affect the quantity and turnover of SOM [19]. That can be explained by lower accumulation of SOC in soils at lower altitudes, as they have more favorable conditions for mineralization than soils at higher altitudes. In our research, a decreasing trend in soil respiration was also found going from the top altitudes to the bottom of the mountain. However, there were no significant differences between sites 1 and 2 in basal and cumulative soil respiration. The same trend was observed with coefficient *k*. However, Sariyildiz and Kücük [49] reported the opposite results for the 2-year litterbags experiment in Northeast Turkey. They found the decrease in soil respiration with an increase in altitude, but noted higher values on the north-facing sites compared to the south-facing sites due to different microclimate conditions and soil characteristics. Topographical landforms (aspects and altitudes) can create different environmental conditions that alter local microclimate and soil characteristics [50], and in turn these changes can retard or accelerate litter decomposition rates through negative or positive effects on the activity of organisms.

Higher concentrations of SOC, total N, and C/N ratio were found in the 0-10 cm layer than in the 10-20 cm layer. Higher concentrations of SOC in the top layer have also been reported by various authors [44, 51, 52]. Soil respiration was also higher at soil depths of 0-10 cm than in 10-20 cm, corresponding to the concentration of organic C and total N in the soil depths. Coefficient *k*, which indicates the rate of mineralization, showed the same behavior.

Conclusions

This study has shown that land use system and altitude are important factors regulating SOM decomposition by altering natural soil characteristics under the same climatic-ecological conditions.

A comparison of the SOC stock values (0-20 cm depth) of different land uses shows that the highest SOC stock was under forest, then arable land, and the lowest under grassland, in contrast to general knowledge.

On average for all land use, SOC stock decreases with decreasing altitude. As cumulative soil respiration and coefficient *k* were greater for sites at higher altitudes (1,500 and 1,000 m), this indicates their lower resilience ability, and emphasis should be put on the preservation of SOC stock at higher altitudes. The protection of forest ecosystems is most important as the greatest SOC stock was found under this ecosystem.

There is a lack of SOC stock data for Serbia. In the course of monitoring SOC stock changes and protection of SOM from degradation, there is a need for estimation of current SOC status stratified by land use, management, soil types, and climate. Knowing SOC stocks could help to identify areas of land uses that are of particular interest for gains and losses of SOC.

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