

ORGANIC CARBON STOCK IN PASTURE LANDSCAPES ON THE TERRITORY OF THE CENTRAL BALKAN NATIONAL PARK

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Abstract

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Aim of study is to determine the org. C stock in georeferenced sample plots on the territory of the Central Balkan National Park for the purposes of long-term observations and assessment of its change under the influence of natural and/or anthropogenic factors. The org. C stock was determined in 17 sample plots, arranged in pastures from the low-mountain, mid-mountain and high-mountain landscapes. The impact of the altitude on the org. C stock, bulk density of fine earth, total nitrogen and the ratio org. C/N was assessed within the range from 535 m to 1878 m. A positive correlation was determined between the org. C stock and the change in altitude, as well as a negative one between the bulk density of soils and the altitude. Significant differences in the org. C stock were determined according to the soil units. The results of the org. C stock in soils from georeferenced locations from low, mid and high-mountain landscapes can be used to develop time data series for the purposes of long-term observations and assessments.

Key words: organic carbon stock; pasture; monitoring; org.C/N; time series; national inventory

Introduction

The content of organic carbon (org. C) and total nitrogen, as well as their ratio, are indicators of soil fertility, impact of climate change and nitrogen depositions in soils (ICP Forest Manuals – Cools and De Vos, 2016). It is considered that the org. C content is strongly dependent on the type of vegetation cover, whilst the org. C stock depends mainly on the climatic conditions. The increase of org. C stock is associated with increases of precipitation and quantity of clay in soils, and its decrease – with temperature elevations (Esteban et al., 2000). Some authors are skeptical about the impact of high temperatures on the decomposition processes as the different organic compounds in soils have a wide range of kinetic properties which complexly determine their sensitivity to the factual temperature of their decomposition (Davidson et al., 2006).

✓ The org. C stock in soils on the territory of Bulgaria has been calculated mainly by soil types. According to some authors the calculated value is 1.3 Gt (Boyadgiev et al., 1994), and according to others – 1.5 Gt (Filcheva, 2007; Filcheva et al., 2002 a; Filcheva et al., 2002 b; Filcheva et al., 2004). The calculations by the type of land use were made for the first time by Doncheva et al. (2009-2010), and were applied in the national inventory “Emissions and greenhouse gas removals from different land-use types, changes in the land-use and forestry” (NIR, 2010). The value of 81 t C.ha⁻¹ was adopted as a reference value for org. C stock in 30 cm soil layer in pasture areas in Bulgaria. That value was obtained as a mean value of the available country data about the org. C content in soils according to literature references (Dzhingov et al., 1994; Vuteva et al., 2005; Vuteva et al., 2008; Stoeva et al., 2008). The analysis of the used information indicates that this value is primarily related to pastures in agricultural lands.

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✓ No long-term information has been collected about the org. C content in soils from different types of pastures in accordance with the way of land use and under various climatic and other conditions. In order to improve the national inventory and apply a higher methodological level – level II (IPCC GPG, 2003; 2006), it is reasonable to collect a chronological data series as a prerequisite to determine the annual variation of carbon stock in soils from different pasture types.

The objectives of this study is to determine the org. C stock in georeferenced sampling locations from the pasture landscapes of the “Central Balkan” National Park, which will enable the creation of time series of org. C stock in order to perform assessments of the changes occurring under the impact of alterations of climatic and other factors.

Materials and Methods

The Central Balkan National Park occupies an area of 72021.07 ha and protects self-regulating ecosystems of exceptional biodiversity, communities and habitats of rare and endangered species. The tree stands occupy 44220.0 ha and the remaining area is consisted of pastures, meadows, grasslands, non-forest areas, rocks and screes (FMP, 2001-2010; 2014-2023). The altitude is from 500 m to 2376 m. The average duration of the periods with persistent air temperature below 0°C varied within the altitude range from 600 to 1600 m, and was between 50 and 120 days for the northern slope and between 47 and 118 days for the southern one (Koleva-Lizama, 2015). One of the highest average annual precipitation values were determined in the region, as in the highest areas the winter precipitation was predominantly snow and the snow cover lasted up to 6 months (FMP 2014-2023).

When analyzing the terrain characteristics and soil-forming rocks in the grassland landscapes of the park territory, Karatoteva (2015) determined the presence of 70 relatively homogenous landscape units, suitable for conducting various research activities. For the purpose of this study these units were used in the selection of subjects, as the aim was to achieve a greater variety of factors affecting the soil formation. Ten of the plots were from previous studies (Malinova, 2015; Malinova, 2016; Karatoteva et al., 2016), which were complemented with 7 new sample plots for the purposes of the present research. Only territories, used as pastures in the landscapes of the low-mountain (altitude up to 1000 m) – 2 sample plots (SP), mid-mountain (altitudes from 1000 to 1500 m) – 7 SP and of the high-mountain belt (above 1500 m) – 8 SP, were selected for the purpose of the study. No fertilization, liming or any other soil-improving measures were implemented in the pastures. It was assumed that this enables the assessment of org. C stock in georeferenced sample

plots, located in the altitude range from 535 m to 1878 m, which reflects the influence of different climatic conditions on it.

The ratio org. C/N as an indicator of the decomposition processes of organic matter in soils was also assessed. It is one of the stable over time indicators Ukonmaanaho et al. (2010) and its low values indicate a greater quantity of accessible for plants nitrogen and a higher microbial activity in soils – ICP Forest Manuals (Cools and De Vos, 2016).

The laboratory analyses included: content of organic carbon – modified method of Turin (Kononova, 1963; Filcheva and Tsadilas, 2002a); bulk density of fine earth – ISO 11272; total nitrogen – method of Kjeldahl (Kjeltec, 1030).

Results and Discussion

The org. C content in the studied soils varied in a wide range between the different soil units as well as within a certain soil unit (see Table 1). The comparison by soil units indicated that the org. C content in the surface 10 cm soil layer of Umbrisols was higher ($125.1 \pm 33 \text{ g.kg}^{-1}$) than in the Regosols ($49.0 \pm 27 \text{ g.kg}^{-1}$) and in Leptosols ($41.4 \pm 32 \text{ g.kg}^{-1}$). The org. C content in soils of the park territory has also been studied by other authors. For example, in the high-mountain pasture of the Beklemeto region, Zhiyanski (2008) determined the average value of org. C in the surface 10 cm layer – 104.7 g.kg^{-1} , which is comparable with the results obtained in this area and presented in Table 1. An increase of the org. C content in the surface 10 cm soil layer was determined in parallel with the increase of the altitude as illustrated on Figure 1. The correlation is expressed by $r=0.70$. It became lower ($r=0.56$) when the analysis included the results for SP13, SP14 and SP 15, where the soils were highly eroded and the analyzed samples were obtained from a 5 cm depth layer.

The calculations of org. C stock in the studied soil profiles indicate that in Umbrisols it was $344.1 \pm 13 \text{ t.ha}^{-1}$, in Regosols – $122.0 \pm 11 \text{ t.ha}^{-1}$ and in Leptosols – $70.4 \pm 50 \text{ t.ha}^{-1}$. The great variation of the org. C stock is due to the soil depth of the studied soils which frequently was highly reduced. However, the analysis performed only in the 10 cm surface soil layer also revealed a great variation – the average value in Umbrisols was $74.56 \pm 24 \text{ t.ha}^{-1}$, in Regosols – $42 \pm 24 \text{ t.ha}^{-1}$ and in Leptosols – $27 \pm 17 \text{ t.ha}^{-1}$. The determined relation between the org. C content and the altitude was also confirmed for the org. C stock. A positive correlation was determined. However, the correlation coefficient values for the layers 0-10 are lower ($r=0.46$) in comparison with those for the org. C content ($r=0.70$). The lower correlation is due to different factors but one of the most significant is the bulk density of the fine earth which is used in the calculation of the org. C

Table 1

Landscape characteristics – altitude, parent materials, soil group and qualifier, location of sample plots – latitude and longitude, carbon and nitrogen contents, bulk density of fine earth (BDfe) and org. C stock

Site №	Altitude m	Parent materials	Soil group	Qualifier	Sample plots - Latitude and Longitude	Depth	Org. C	Total N	BDfe	Org.C Stock
						cm	g.kg ⁻¹	g.cm ³	t.ha ⁻¹	
Landscapes of low-mountain pastures										
1	535	schist	Regosols	Dystric	42°39'11.3"N 24°48'35.7"E	0-10	16.4	2.33	1.05	17
						10-20	14.4	1.72	1.08	16
2	947	phyllite	Regosols	Eutric	42°44'13.1"N 24°13'09.3"E	0-10	28.4	2.1	1.05	30
						10-20	8.4	0.9	1.14	10
Landscapes of mid-mountain pastures										
3	1100	limestone	Leptosols	Rendzic	42°40'51.0" N 24°57'35.0" E	0-10	38.1	4.03	0.85	32
						10-30	32.8	3.03	0.98	64
4	1165	weathering materials from granite	Regosols	Eutric	42°44'04.7" N 24°29'10.9" E	0-10	69.7	6.63	0.78	54
						10-30	60.6	4.83	0.85	103
5	1248	slope deposits	Deluvial Fluvisols	Eutric	42°40'51.0" N 24°58'45.0" E	0-10	71.8	5.30	1.12	80
						10-30	60.2	5.30	1.03	124
6	1270	weathering materials from gneiss	Regosols	Eutric	42°44'42.0" N 24°36'46.0" E	0-10	62.5	4.70	1.04	65
						10-30	51.1	3.93	0.88	90
7	1384	weathering materials from schist	Regosols	Dystric	42°41'20.0" N 25°06'50.0" E	0-10	98.1	12.15	0.89	87
						10-30	87.3	8.53	0.80	140
8	1448	siltstone	Regosols	Dystric	42°45'35.2" N 25°07'47.6" E	0-10	18.3	1.94	0.96	18
9	1445	schist and sandstone	Cambisols	Dystric	42°46'26.8" N 24°39'07.3" E	0-10	73.3	8.05	0.83	61
						10-30	48.4	4.61	0.88	85
Landscapes of high mountain pastures										
10	1529	schist	Umbrisols	Haplic	42°46'53.3" N 24°36'14.6" E	0-10	143.2	13.43	0.62	89
						10-30	134.9	11.60	0.74	200
11	1536	granodiorit	Umbrisols	Haplic	42°46'52.2" N 24°20'01.3" E	0-10	75.3	5.77	0.53	40
						10-30	63.0	5.41	0.70	88
12	1542	siltstone	Regosols	Dystric	42°45'29.0" N 25°06'55.5" E	0-10	47.5	5.34	0.82	39
						10-30	27.3	3.29	0.84	23
13	1578	siltstone	Regosols	Eutric	42°45'21.0" N 24°37'35.4" E	0-5	51.3	4.1	1.16	30
						5-20	27.2	2.4	1.18	48
14	1578	carbonate siltstone	Leptosols	Rendzic	42°45'33.7" N 24°37'31.9" E	0-5	44.5	2.0	1.10	24
						5-15	35.2	2.0	1.12	39
15	1581	limestone	Leptosols	Rendzic	42°45'20.7" N 24°37'35.9" E	0-5	41.8	2.9	1.18	25
						5-15	30.40 30.40	3.6	1.20	36
16	1635	schist	Umbrisols	Haplic	42°46'04.0" N 24°39'51.0" E	0-10	144.2	11.06	0.65	94
						10-30	138.1	13.52	0.97	268
17	1877	weathering materials from granite	Umbrisols	Haplic	42°42'36.6" N 24°58'52.9" E	0-10	137.9	11.43	0.55	76
						10-30	122.0	9.94	0.67	163

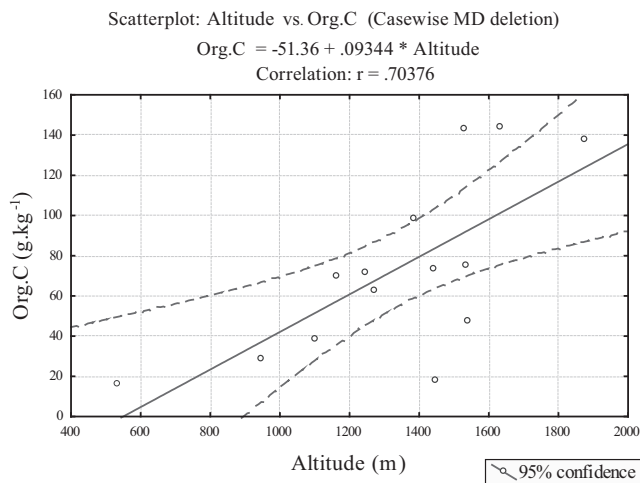


Fig. 1. Relation between the altitude and the org. C content in the surface 10 cm soil layers

stock (Figure 2). Its values change in the opposite direction – they decrease with the increase of altitude ($r = -0.46$). The calculated average value of fine earth bulk density in Umbrisols was $0.67 \pm 0.13 \text{ g.cm}^{-3}$, in Regosols – $0.95 \pm 0.12 \text{ g.cm}^{-3}$ and in Leptosols – $1.03 \pm 0.10 \text{ g.cm}^{-3}$. Statistically significant differences in the bulk density values between Umbrisols and Regosols ($p = 0.0005$) as well as between Umbrisols and Leptosols ($p = 0.0002$) were determined.

The performed analysis indicates that there is a great variation of the org. C stock within the boundaries of the pasture landscapes which makes the assessment of its change over time uncertain.

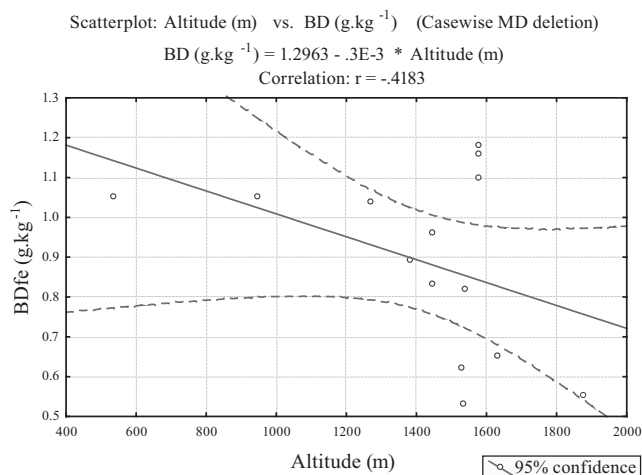


Fig. 2. Relation between the altitude and the bulk density of fine earth (BDfe) of the surface 10 cm soil layers

The issue about the precise definition of soil units in the mountain territories should also be added to this uncertainty. For example, according to the soil map of the “Central Balkan” National Park (FMP 2014-2023), on its territory are determined Cambisols, Umbrisols, Luvisols and Leptosols. The conducted field studies indicate that for the 17 soil profiles, which according to the map are located in territories with Cambisols or Umbrisols, in 10 of them the soils are of other soil units. In 8 they are determined as Regosols, and in 1 soil profile as Deluvial Fluvisols. The presence of Cambisols was also determined in one of the profiles on a territory with Umbrisols. The values of org. C stock, presented in Table 1, are representative for a specific landscape-ecological unit, differentiated according to the similarity of the soil-forming factors (soil-forming rocks and terrain components – altitude, exposure and slope), rather than for a specific soil unit. The information by soil units reflects the great variation of the org. C stock due to the influence of the altitude (climatic conditions, respectively) in territories with great altitude differences. According to Vangelova et al. (2016) one of the sources of errors and uncertainties of the research is the “lack of local and regional representativeness of sampling plots”. The landscape of the “Central Balkan” National Park is characterized by a complex vertical structure, greatly influenced by the topography. In this research, the change in altitude is considered an important factor that affects the accumulation of organic matter in soil due to the consequential change of climatic conditions. The determined dependences prove that taking into consideration their characteristics can improve the accuracy of the study.

The relation between the org. C content and total nitrogen in the surface soil layers is confirmed with $r=0.93$, and between their stocks – with $r = 0.91$. However, the impact of the altitude variation has a much lower impact on the quantity of the total nitrogen in comparison with the quantity of org. C. The correlation is weak ($r = 0.44$), and regarding the total nitrogen stock it is even weaker ($r = 0.21$). The ratio between the two elements – org. C/N is also characterised by a weak correlation in accordance with changes in altitude ($r = 0.35$). Its average value of the surface soil layer in soils of the mid-mountainous belt is 10 ± 2 and 13 ± 4 of the high mountainous belt, respectively. No statistically significant differences were confirmed between them which mean that regardless the altitude, the conditions for decomposition of organic matter in the studied pastures are favourable. In similar studies some authors determined differences in the ratio org. C/N but they concerned only sites at the lowest (3000 m) and highest (4000 m) locations (Zhang et al., 2011). According to the same authors, the exposures have a greater impact on the ratio org. C/N than the altitude.

Conclusions

The org. C content and stock in the soils of the pasture landscapes of the “Central Balkan” National Park varies greatly. The altitude, climatic conditions, bulk density of fine earth and soil depth were determined as the main factors of impact. The uncertainty in the org. C stock assessments in large areas is due to the insufficient definition of the soil units within the park boundaries.

This study presents results of the org. C content and stock in soils from georeferenced locations that can be used for long-term monitoring of changes occurring in pastures from low, mid and high-mountainous landscapes. The development of time data series will improve the accuracy of future assessments.

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