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Comparative analysis of soil organic carbon in selected river catchments

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ABSTRACT

The present study deals with the investigation of soil organic carbon in two water catchments in Northern Rila Mountain. Field research, combined with analysis, provided sufficient data. Six key sites were selected and sampled in order to estimate and compare the amount of organic and inorganic carbon in the topsoil. The applied criteria for the choice of sites included: vegetation cover, predominant soil group, level of anthropogenization and transport accessibility. A total number of 13 samples from both catchments were collected and analyzed in the Central laboratory of the Institute of Soil Science, Agrotechnologies and Plant Protection (ISSAPP) "N. Pushkarov". The results concern the amount and composition of soil organic matter in different soils – Cambisols (Albic, Humic, Dystric), Fluvisols and Umbrosols. The total carbon content of all samples varies between 1.23 and 9.69%. The amount of organic carbon ranges between 0.45 and 3.73%. The results of the study prove once again that the preservation of natural vegetation and current condition of the soil is of great importance for carbon sequestration and climate change mitigation.

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1. Introduction

We live in a constantly altering environment. We face the everyday results of climate change. The aftermath of the COP27 in Egypt is clear. Adaptation and mitigation measures have to be adopted. Climate change mitigation has an objective - to decrease the carbon stock in the atmosphere. Carbon is released to the atmosphere via a number of natural processes, accompanied by anthropogenic activities, like fossil fuels burning. Global carbon sequestration is still one of the most discussed and evaluated processes to battle climate change. Carbon sequestration is a long-term capture and storage of carbon dioxide from the atmosphere into a wide range of ecosystems, acting as carbon pools (soils, plants and the ocean). This effect is well-recognized by scientists. A well-known fact is that when carbon reaches the atmosphere, it adds weight to the greenhouse effect. The participants in International initiatives like the "4p1000 Initiative: Soils for Food Security and Climate" are striving for results. The ocean's, forests' and soil's role in carbon sequestration is widely recognized. Together they act as a catalyst for storing carbon.

Scholars around the globe have put a lot of effort in the research of carbon sequestration. Scharlemann et al. (2014) focused on the understanding and management of the terrestrial carbon pool. Schuur et al. (2015) conducted an investigation, basing on the permafrost carbon feedback. Corbeels et al. (2016) investigated the Cerrado of Brazil with a focus on soil carbon sequestration. Hodgking et al. (2018) studied tropical peatland carbon storage. Sayer et al. (2019) put their efforts in the study of tropical forest soil carbon. Bhardwaj et al. (2019) investigated the impact of carbon inputs on soil carbon fractionation.

Bulgarian scientists also gave their share in carbon research. Tsolova et al. (2014) studied the presence of different elements, including carbon, in Technosols. Zhiyanski et al. (2016) mapped carbon storage in the Central Balkan Range.

Carbon sequestration de facto an essential ecosystem service and there is rich bibliographical reference on this matter in Bulgaria. Bratanova-Doncheva et al. (2017) and Zhiyanski et al. (2017) conducted a methodological framework for assessment and mapping of ecosystem condition. Nedkov et al. (2021) created a methodological framework for mapping and assessment of ecosystem services. Nikolova et al. (2021) discussed natural heritage as a source of ecosystem services for recreation and tourism. Hristova and Stoycheva (2021) developed a map of the potential of the natural heritage to provide ecosystem services for the needs of recreation and tourism at a national level. Prodanova (2021) conducted an experimental mapping and assessment of ecosystem services. Zhiyanski et al. (2021) discussed the role of cultural ecosystem services in forest territories.

The following paper aims at unveiling soil carbon contents in two river basins (Cherni Iskar and Yadenitsa catchments) located on the northern slopes of Rila Mountain. The content and composition of organic matter is emphasized. This research is a continuation of our previous studies in the same area of interest (Bozhkov et al. 2022).

2. Materials and methods

Cherni Iskar is one of the main tributaries, which together with Beli Iskar (Fig. 1) forms the longest river in the territory of the country – Iskar River (368 km). Yadenitsa is a 29.56 km long river, one of the first major right-bank affluents of the Maritsa River (472 km). The basin of Cherni Iskar is nearly twice as large as the catchment of Yadenitsa River, with the latter having a higher relief (Table 1). The length of Cherni Iskar is 23.33 km, and the distance between the source parts of Chdenitsa and the mouth in Maritsa is 29.56 km. The main right-bank tributary of Cheni Iskar is the river Lakatitsa (13.19 km) and left-bank tributaries are Urdina (10.02 km), Malyovitsa (7.75 km),. Pryaka (7km), Lopushnitsa (7.59 km) and Levi Iskar (17.72 km) (Fig. 1). The Yadenitsa River receives numerous short tributaries, among which the larger ones are Kalunichno dere (7.65 km), Bazenishko dere (5.77 km), Belovodsko dere (5.65 km), Yundolska reka (5.49) and Skriynitsa (4.85).

Numerous lakes of glacial origin were formed within the watershed of the Cherni Iskar River such as Urdini lakes, Malyovishki lakes, Dolnolevorechki lakes, Izola lake, Chanakgyol lake etc. They have a small area (less than 0.1 km^2) and are located above 2000 m above sea level. In contrast, the Yadenitsa river catchment is not characterized by the presence of lakes. Both basins are covered predominantly by coniferous forests and mountain meadows (mainly in the upper course) associated with soils such as Cambisols and Umbrosols. Litic and Umbric Leptosols with depth less than 50 cm are also present in the alpine and subalpine zone of the Rila Mountain.

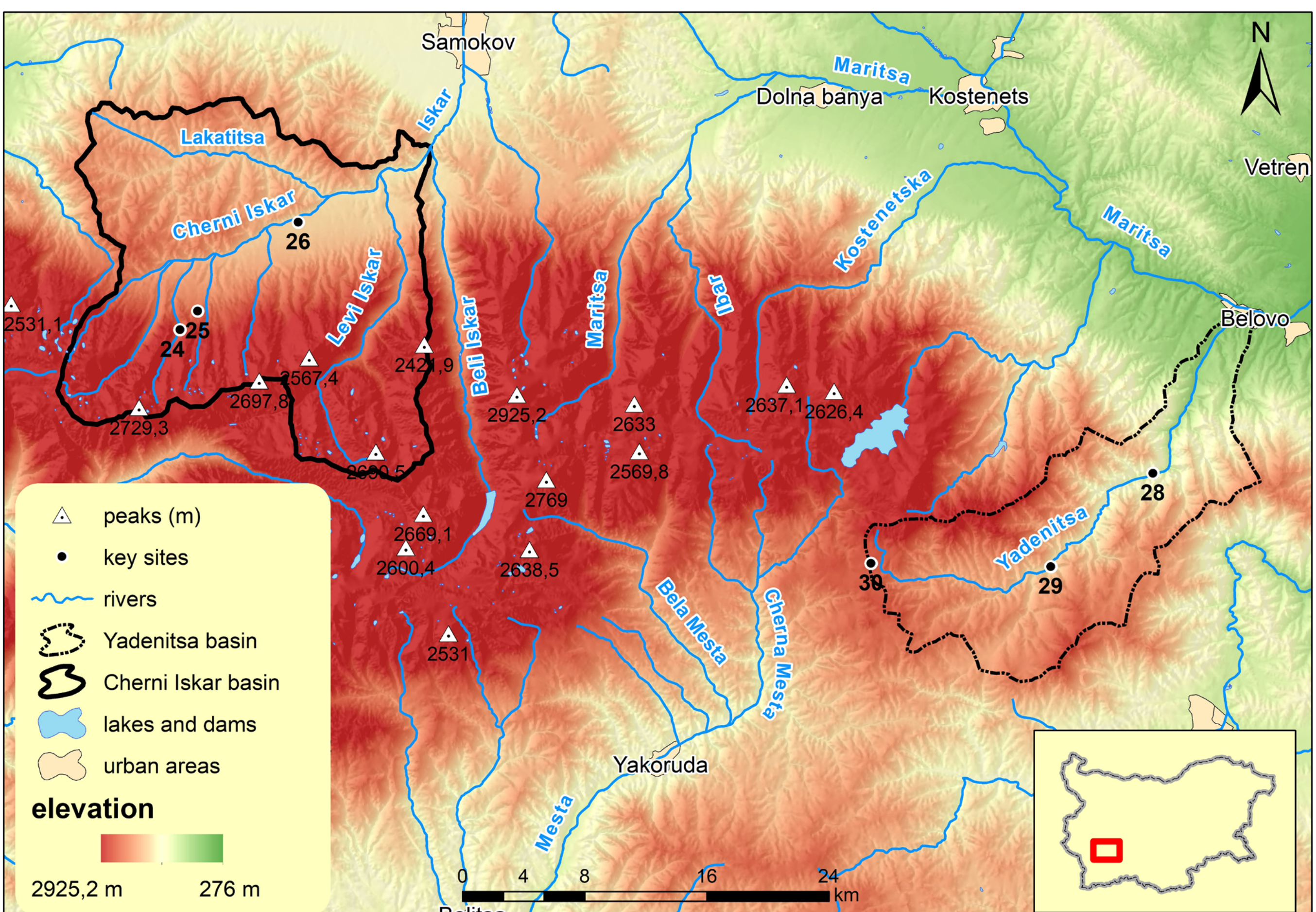


Figure 1. Location of the study areas

Table 1. Main morphometric parameters of the studied basins

Parameter	River Basin	
	Cherni Iskar Basin	Yadenitsa Basin
Area (km^2)	237.49	138.04
Perimeter (km)	79.12	66.20
Maximum elevation (m)	2738.52	2168.63
Minimum elevation (m)	1033.86	308.39
Mean elevation (m)	1730.96	1325.69
Relief (m)	1704.66	1860.24

Three key sites in each river basin were selected and sampled in order to estimate and compare the amount of organic and inorganic carbon in the topsoil (at depth 0-5 cm). Sites were chosen by several criteria such as vegetation cover, predominant soil group, level of anthropogenization and transport accessibility. A total number of 13 samples from both catchments were collected and analyzed in the laboratories of the Institute of Soil Science, Agrotechnologies and Plant Protection (ISSAPP) "N. Pushkarov". All samples are tested in the Central laboratory of the Institute of Soil Science, Agrotechnologies and Plant Protection (ISSAPP) "N. Pushkarov", Sofia. The total carbon content is determined by the test of Turin after Kononova (1963). Thus the humus content is calculated by multiplying the percentage of total carbon by 1.724.

Soil carbon content is expressed as total carbon and organic carbon. The organic carbon is determined as a proportion of the entire soil sample, as well as a percentage of total carbon. Total content of humic and fulvic acids is determined after extraction with a mixed solution of 0.1 M (molar) Na_4P2O_7 and 0.1 M (molar) NaOH.The type of humus is defined by the ratio between carbons of humic acids to fulvic acids – C_h/C_f. This ratio is an indication of climate conditions during the soil formation. The higher amount of Cf indicates a weak process of humification, determined by cold and humid climate and presence of forest vegetation, whereas humic acids predominate under herbaceous vegetation. Results are presented as tabular data.

3. Results

The territory of research includes the water catchments of Cherni Iskar and Yadenitsa Rivers. Table 2 displays the territorial distribution in percentage of CORINE Land Cover (CLC) Classes for 2018, while a map is presented in Figure 2.

Coniferous forests are dominating the ecosystems of both territories. They are covering 41.78% of the Cherni Iskar River Basin and 39.68% of the Yadenitsa River Basin. Artificial surfaces, which include codes, starting with the CLC code "1" and agricultural areas, starting with the CLC code "2" are taking up a small share of the territories. There is a big difference of the areas with broad-

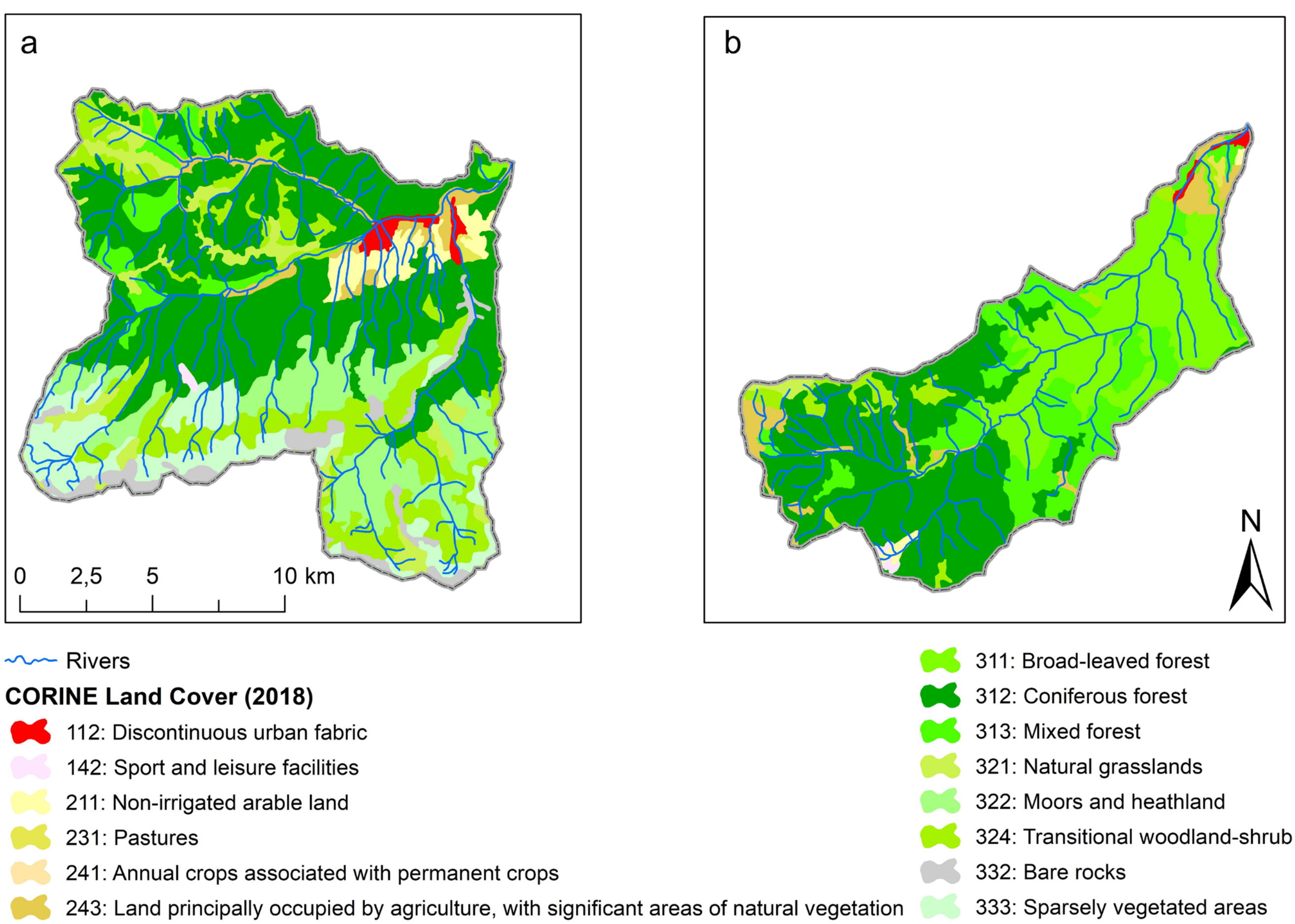
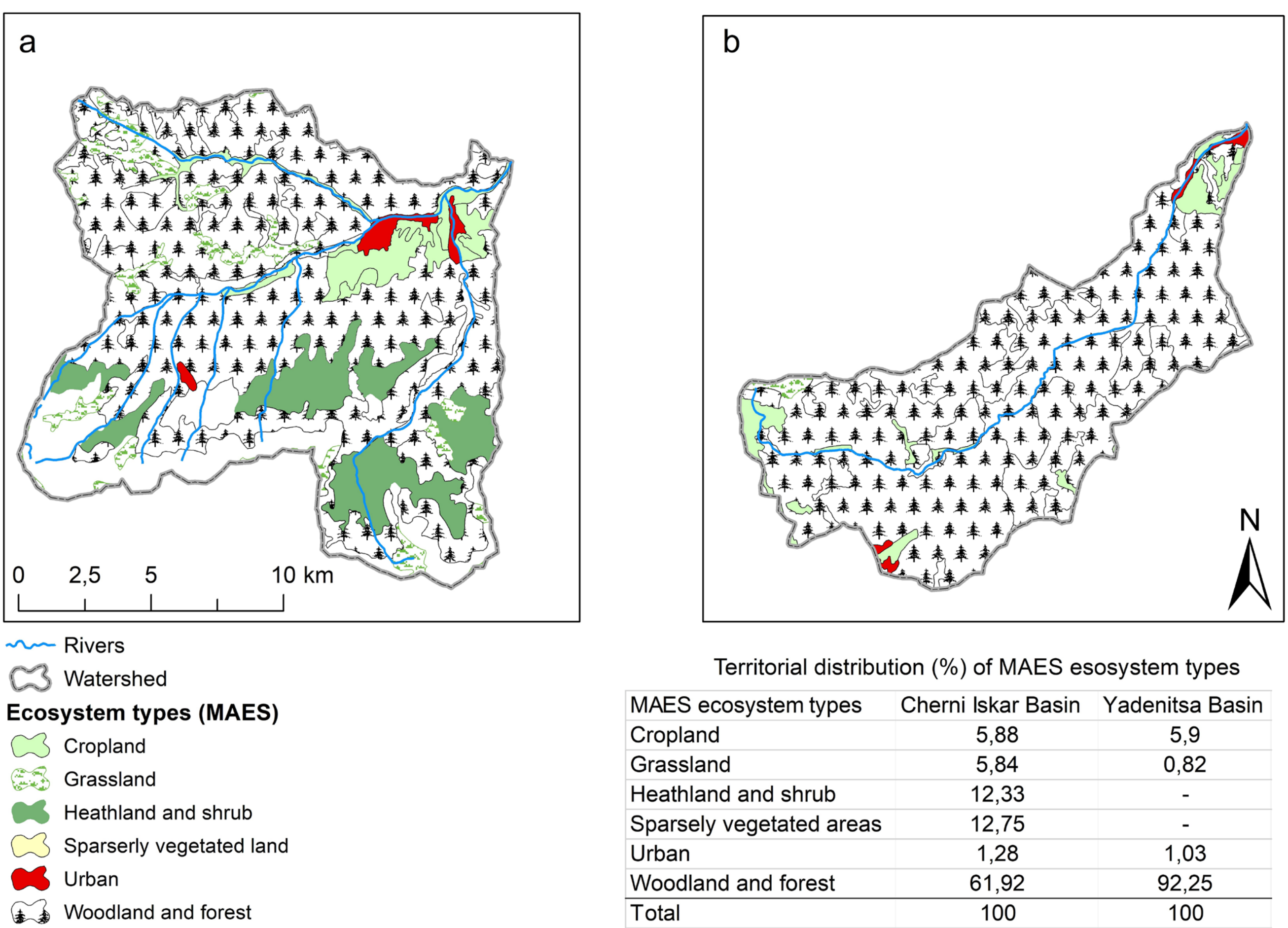


Figure 2. Land cover pattern Cherni Iskar (a) and in the Yadenitsa River Basin (b)

Table 2. Territorial distribution (%) of CORINE Land Cover (CLC) classes 2018

CLC	Level 3 nomenclature	Cherni Iskar Basin	Yadenitsa Basin
112	Discontinuous urban fabric	1.12	0.67
142	Sport and leisure facilities	0.17	0.36
211	Non-irrigated arable land	2.92	0.73
231	Pastures	0.19	0.37
243	Land principally occupied by agriculture, with significant areas of natural vegetation	2.77	4.80
311	Broad-leaved forest	0.22	29.00
312	Coniferous forest	41.78	39.68
313	Mixed forest	3.83	19.01
321	Natural grasslands	5.84	0.82
322	Moors and heathland	12.33	–
324	Transitional woodland-shrub	16.09	4.55
332	Bare rocks	3.88	–
333	Sparsely vegetated areas	8.87	–
	Total	**100**	**100**



Territorial distribution (%) of MAES esosystem types

MAES ecosystem types	Cherni Iskar Basin	Yadenitsa Basin
Cropland	5,88	5,9
Grassland	5,84	0,82
Heathland and shrub	12,33	-
Sparsely vegetated areas	12,75	-
Urban	1,28	1,03
Woodland and forest	61,92	92,25
Total	100	100

Figure 3. Ecosystem types following the MAES Typology

leaved forests. The lower mean elevation levels of the Yadenitsa Basin (1325.69 m a.s.l.) serves as an explanation of this fact. The same explanation may be applied in the discussion of the presence of moors and heathland in Cherni Iskar's Basin (12.33%) and their absence in the other basin. There are two more classes that do not occur in the basin of Yadenitsa River: bare rocks and sparsely vegetated areas.

The CORINE Land Cover classes were used to derive the Maes ecosystem types (2013, 2014) that may be viewed in Figure 3. The river basin of Cherni Iskar includes six ecosystem types, while Yadenitsa River's Basin lacks the types of heathland and shrub and sparsely vegetated areas, mainly because of its lower altitude. At the same time more than 90% of its area is covered by woodland and forest, opposing to the 61.92% coverage in the basin of Cherni Iskar. Croplands and urban territories are taking almost equal shares in the two basins. The higher mean elevation of Cherni Iskar Basin (1730.96 m a.s.l.), accompanied by anthropogenic activities have resulted in the presence of more grasslands (5.84%), compared to 0.82% in Yadenitsa's Basin.

The field research in the two water catchments was carried out in 2021. It included soil sampling, aiming at the investigation of soil organic carbon.

Tables 3 and 4 present data about the content and composition of soil organic matter. Six key sites were investigated and thirteen soil samples were extracted.

Key site 24, 25 and 26 are located in the basin of Cherni Iskar River (Fig. 1). Site 24 is located nearby Malyovitsa hut at about 1738 m a.s.l. and represents a typical transitional area between subalpine forests and alpine grasslands. At that place coniferous forests with birch (*Betula pendula*) and shrubs are involved in the formation of Dystrict Cambisols. Several samples are taken from different pedons within the site. Sampe 24-1 is taken from an area with coniferous shrubs (*Pinus mugo*), whereas sample 24-3 is obtained under a forest vegetation (*Pinus sylvestris* and *Pinus peuce*) with undergrowth of berries (*Vaccinium sp.*) and grasses. Sample 24-2 is taken form the right bank of Malyovitsa River under coniferous forest. Vast differences are observed in both total carbon and humus content (Table 3). The organic carbon in all samples from this site is less than 2% of the soil composition. The prevalence of fulvic acids over humic acids in samples 24-1 and 24-2 is related with the presence of coniferous vegetation. The C_f/C_h ratio of sample 24-3 (Table 3) is related to the herbaceous vegetation. The most carbon is sequestered in the soils developed under coniferous shrubs (sample 24-1).

Site 25 is located at 1622 m in the downstream of Cherni Iskar, on a watershed between Razhdavitsa and Pryaka rivers. The vegetation is mixed, represented by spruce (*Picea abies*) and sycamore (*Acer pseudoplatanus*) with an understory of deciduous shrubs and numerous grasses. Two samples are taken from soil under pine (sample 25-1) and broad-lived vegetation (sample 25-2). The total carbon content and humus respectively in sample 25-1 is the highest

Table 3. Indicators for content and composition of soil organic matter (Cherni Iskar Basin)

				Organic carbon (% of total carbon)		
Sample	Total carbon (%)	Humus (%)	Organic carbon (% of the soil sample)	Humic acids (C_h)	Fulvic acids (C_f)	C_h/C_f
24-1	6.49	11.18	1.99	13.41	17.25	0.78
24-2	1.23	2.12	0.45	17.89	18.70	0.96
24-3	4.54	7.83	1.51	18.28	14.89	1.22
25-1	9.69	16.71	3.72	22.19	16.20	1.37
25-2	5.76	9.39	2.88	32.29	17.71	1.82
26-1	2.58	4.45	0.81	19.38	12.02	1.61
26-2	4.36	7.52	1.27	14.68	14.45	1.02

Table 4. Indicators for content and composition of soil organic matter (Yadenitsa Basin)

				Organic carbon (% of total carbon)		
Sample	Total carbon (%)	Humus (%)	Organic carbon (% of the soil sample)	Humic acids (C_h)	Fulvic acids (C_f)	C_h/C_f
28	7.68	13.24	0.80	4.56	5.86	0.78
29	5.69	9.98	1.10	10.72	8.61	1.24
30-1	6.09	10.50	1.92	15.11	16.42	0.92
30-2	5.59	9.64	1.38	12.16	12.52	0.97
30-3	3.44	5.93	1.15	16.28	17.15	0.95
30-4	4.22	7.28	1.44	19.91	14.21	1.40

from all tested soils. Therefore, the coniffeous trees has importance of in carbon sequestration is significant. The values of C_f/C_h ratio indicate dominance of humic acids (Table 3) due to the existence of grass canopy.

Key site 26 is located about 0.53 km to west from the village of Govedartsi at 1184 m a.s.l. in the Valley of Cherni Iskar. It is a typical example of mountain meadows with shrub layer including species as *Juniperus communis*, *J. sibirica*, *Pinus sylvestris* and *Rosa canina*. Two samples were collected – one from a pedon (Humic Cambisols) with herbaceous canopy (sample 26-2) and the other is beneath shrubs (26-1). The total carbon sequestrated in this site varies from 2.58 up to 4.36 (Table 3) depending on vegetation cover. In addition, it is observed that fulvic acids exceed the amount of humic acids, which is more evident in sample 26-1.

Three sites with different elevation were samples in the catchment of Yadenitsa Raiver. Sites 28 (located at 829 m) and site 29 (1135 m) are situated in the forest zone while site 30 (1745 m) represents the upper limit of the forest. Unlike the previous three sites which are included in within the extent of "Rila" National Park, all sample areas in the Yadenitsa Basin are not part of a protected area.

Key site 30 is located in adjacency to Hristo Smirnenski Hut and it is a prime example of land cover 243 (Fig. 2). Here the natural vegetation in highly influenced by the anthropogenic activities such as timber logging, cropping potatoes and grazing livestock. As a result, natural spruce forests have decreased in area at the expense of mountain meadows. Four samples are taken from this site in order to estimate the variance in soil organic carbon. Sample 30-1 is taken from the topsoil beneath spruce trees, while 30-2 is taken under a willow tree (*Salix caprea*). The other two samples (30-3 and 30-4) are samples are acquired from soil under herbaceous vegetation and near a wetland, respectively.

The organic carbon from all samples in site 30 is less than 2% (Table 4), although the total carbon tends to be 3-4 times higher. The humus content varies from 5.9 up to 10.50% as the maximum values are registered in soil with coniferous and deciduous trees (samples 30-1 and 30-2). Ch/Cf ration indicates approximately equal proportion of fulvic acids and humic acids in all samples except 30-4 (Table 4). The dominance of humic acids in this sample might be explained with the presence of grassland vegetation in an area with excessive moisture. Sample 30-3 represents typical Orthic Umbrosols with high humus content in the topsoil horizon.

Key site 29 is located 10 km downstream in the valley of Yadenitsa River on a floodplain with a riparian vegetation (presented by *Alnus viridis*) and Fluvisols. The amount of total carbon and humus is a bit lower than site 30 (sample 30-1), although the organic carbon is twice as low. Most of it is stored as humic acids (due to the effect of broad-leaved trees and undergrowth on soil formation) which reflects the value of Ch/Cf ratio (Table 4).

Site 28 is located at the vicinity of Rila Mountain at elevation of 829 m. It is a typical example of deciduous oak forests (*Fagus sylvatica*), formed on Albic Cambisols with an understory of various shrubs and grass (*Luzula luzuloides*). These soils store about 7.7% carbon and are rich in humus (Table 4). However, the organic carbon content is less than a percent of the total sample, primarily in form as fulvic acids.

5. Conclusion

The studied watershed covers about 375,53 km^2 or around 14,28% of the territory of the entire Rila Mountain (2629 km^2). Collected data describes the proportion of organic and inorganic soil carbon stored in the topsoil horizon of several major soil groups – Cambisols, Umbrosols and Fluvisols. The largest share of the results concern the amount and composition of soil organic matter in different pedons of Cambisols. However, obtained results can be extrapolated for other areas with similar settings (elevation, aspect, vegetation and soil cover). The total carbon content in all samples varies between 1.23 and 9.69%. In the same time the amount of organic carbon ranges between 0.45 and 3.73%. Even in a single site the soil carbon content varies in a wide range depending on local conditions such as the type of vegetation, the presence or absence of an understory, and the species composition of the plants. Therefore, the preservation of natural vegetation and current condition of the soil is of great importance for carbon sequestration and climate change mitigation. Soil organic carbon content changes under the influence of natural and anthropogenic factors. In conclusion, the presented study shows only the most recent state of the landscapes in the context of climate change and can be used as a starting point in a long-term environmental monitoring.

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