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Soil organic matter of Cambisols in Vitosha mountain, Bulgaria

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Abstract: A complex of soil carbon properties was studied and a research was made about the content of soil organic matter and organic C. The surface A and Bw horizon of Cambisols were studied in order understand relations of soil organic content and composition. Sample soil profiles in the middle part of Vitosha Nature Park were taken under different type of trees. Higher amount of total carbon and free low-molecular humic acids were determined in the surface and in the cambic horizons. The amount of soil organic carbon is high – from 2.08 % to 5.44 % in the surface horizon. The fulvic-humic type of soil organic matter predominates in studied soil horizons. Similar to this most of the soil samples have ration C/N > 15 which is Mull humus. This type is commonly associated with temperate forest ecosystems, where deciduous trees shed their leaves annually, and contributing organic matter to the soil.
Keywords: *Fulvic acids, Humic acids, Soil carbon, Soil nitrogen.*

1. Introduction

Vitosha Nature Park is a suitable site for research from an ecological point of view, given the background levels of fine dust as part of the sediments on the soil [1, 2, 3].

Soil organic matter plays a crucial role in forest areas, contributing to soil fertility, water retention, nutrient cycling, and overall environment. Vitosha Nature park has diverse ecosystems ranging from forests and grasslands to wetlands areas. These ecosystems can store substantial amounts of carbon in their soils. Undisturbed soils in the park may contain high levels of soil carbon due to minimal human activity and natural processes of organic matter accumulation.

Cambisols are one of the most widespread soil types from the mountainous climate zone. They are distinguished by the presence of a metamorphic cambic B-horizon, the thickness of which is about three times greater than that of the humus-accumulative A-horizon, coloring in brown tones, undifferentiated profile in terms of texture, clayey-sandy textural composition. These soils are a product of the forest soil-forming process under coniferous and broad-leaved vegetation in the conditions of a moderately cool and humid climate with a well-drained soil profile. The main elementary soil-forming processes are humus formation, acidification in place and low movement of the newly formed products in the profile [4].

Cambisol are main soil type in Vitosha Nature park – Bulgaria, are widespread, occupying main middle parts between 800 and 1600 m a.s.l. of the mountain. A complex of soil organic matter parameters like content, stock type of humus and other was established by Malinova et al. (2019) [5] and a database on the content of soil organic matter and org. C stock. A number of studies have also been conducted related to the microbial abundance of Cambisols and the relationship between it and individual parameters of these soils - such as humus content, organic carbon content, total nitrogen, pH, etc. [6, 7, 8, 9, 10, 11].

Cambisols are soil types characterized by their significant horizon differentiation, where eluviation and illuviation processes have occurred. These processes often lead to the accumulation of organic matter in the upper horizons. Soil organic carbon (SOC) content in Cambisols can vary depending on factors such as climate, vegetation, land use, and soil management practices [12].

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Cambisols have the largest area and respectively the greatest representativeness for the territory of the park. They occupy an altitude of 750 to 1850 m. The main tree species under the influence of which the soil formation process takes place are grown from crops and forests for conversion [13, 14].

The natural conditions for humus formation in Cambisols favor the transformation of organic residues (forest litter) and the formation of humus of the '*mull*' and '*moder*' type. The humus formation condition of these soils distinguishes them from other forest soils of the plains and semi-mountainous regions [15, 16, 17, 18]. Cambisols under natural forest vegetation (beech and coniferous species) are characterized by accumulation of humus at a depth. The humus content in the surface is very high in the lower part of the A horizon, it sharply decreases and in the cambic horizon [19, 20, 21].

The thickness of the A horizon and the content of humus increases with increasing altitude. The determined variation of the humus content, both in the individual soil horizons and for the entire soil profile, is related to the highly pronounced mountain relief, which determines the different water regime of the different relief forms and the different strength of the soil profile. The humus stocks vary widely, both in individual horizons and for the entire soil profile. Fulvic acids predominate over humic acids and the humus type throughout the profile is fulvate [17]. The soil microbiological abundance in Vitosha Mountain shows that Cambisols have a higher value than other soil types. The higher microbial content is concentrated at altitudes between 1200 and 1500 m a.s.l. [7].

The aim of the study is to established soil organic matter content and composition, as well as the factors of soil organic matter formation in the middle part of Vitosha Mountain. Also to facilitate the activities related to preserve soil organic carbon content in forest soils in different type of forests.

2. Object and Methods

Eleven soil profiles of the territory of Vitosha Natural Park were analyzed. They are set in pre-selected territorial areas units, which is obtained after the distribution of the entire area of park by soil type, slope, exposure, altitude, and tree species (Fig. 1). From them 11 soil profiles and 22 soil samples were selected and analyzed all from Cambisol soil type.

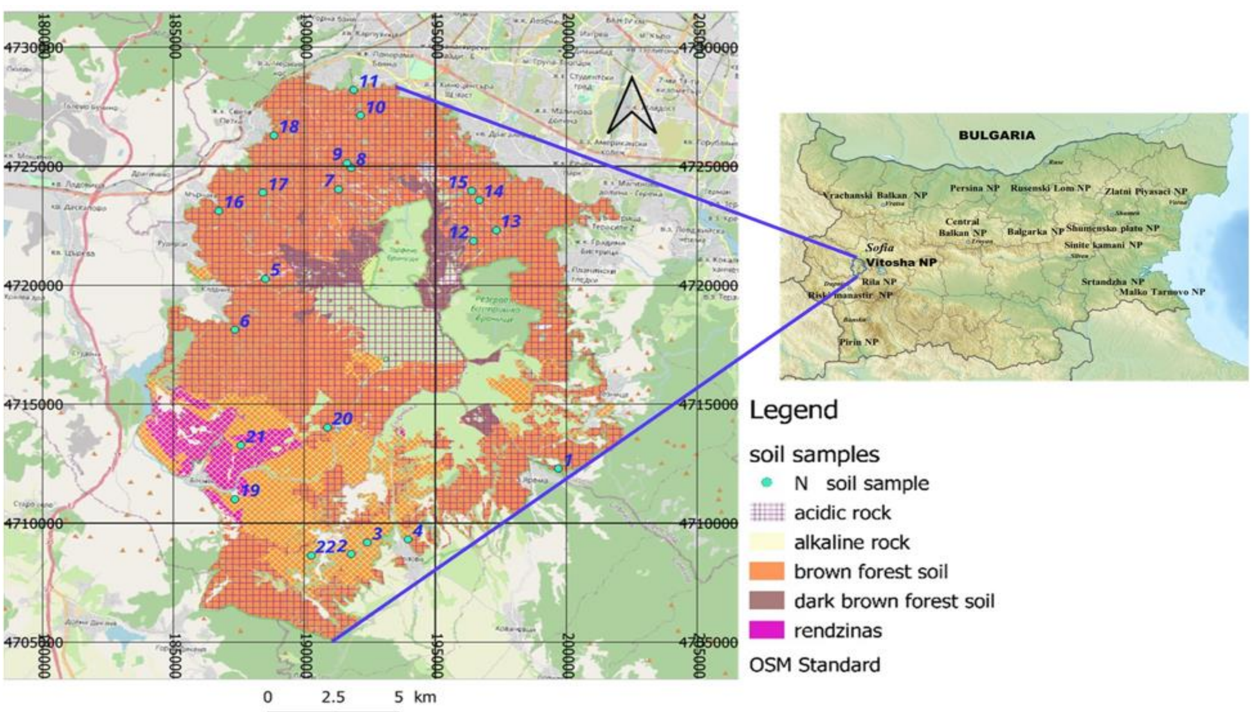

Figure 1.
Places where soil samples were taken in Vitosha Nature Park, Bulgaria.

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Soil organic matter composition was determined by the method of Kononova-Belchikova [22, 23, 24, 25]. Total humic and fulvic acids (C-extacted) after extraction with mixed solution of 0.1M $Na4P_2O_7$ and 0.1 M NaOH; 'free' and R_2O_3 bounded humic and fulvic acids (CNaOH) after extraction with 0.1 M NaOH and the most dynamic, low molecular fraction of organic matter, so called 'aggressive' fulvic acids fraction – 1a extracted with 0.05 M H_2SO_4, ratio soil:solution = 1:20 for the three extractions. Humic and fulvic acids in both extracts Cextr. and CNaOH were separated by acidifying solution with sulfuric acid (0.5 M). For total nitrogen is used Kjeldahl method [26]. Microsoft Excel 2017 is used for graphics and statistics.

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Table 1.
Soil organic matter content and composition, nitrogen content and C/N ratio.

Soil profile /Sample/ Depth, cm	Total C, %	Organic carbon, %			Ch/ Cf	Organic carbon, %		Unextrac organic carbon, %	Optical Properties (E_4/E_6)		Total N, %	C/N
		Extracted with 0.1M $Na_4P_2O_7$+0.1M NaOH				Fraction of humic acids Ch			Total humic acids	Free humic acids		
		Total C, %	Ch, %	Cf, %		Free and bound with R_2O_3	Bound with Ca					
4A 0–10	2.22	0.79	0.45	0.34	1.32	77.78	22.22	1.43	5.24	4.73	0.187	11.87
4Bw 10–68	0.56	0.24	0.00	0.24	-	0.00	0.00	0.32	-	-	0.063	8.89
6A 0–18	3.37	0.84	0.45	0.39	1.15	100.0	0.00	2.53	4.29	5.03	0.30	11.23
6Bw 18–68	1.57	0.64	0.39	0.25	1.56	66.67	33.33	0.93	3.94	4.58	0.169	9.29
7A 0–10	4.05	1.84	1.31	0.53	2.47	57.25	42.75	2.21	5.11	5.07	0.358	11.31
7Bw 10–80	1.37	0.43	0.26	0.17	1.53	100.0	0.00	0.94	4.73	4.18	0.086	15.93
9A 0–13	3.62	2.52	1.60	0.92	1.74	100.0	0.00	1.10	5.46	5.20	0.402	9.00
9Bw 13–78	2.31	0.92	0.60	0.32	1.87	100.0	0.00	1.39	4.98	4.59	0.195	11.85
10A 0–15	3.76	1.40	0.83	0.57	1.46	90.36	9.64	2.36	4.47	4.22	0.366	10.27
10Bw 15 57	1.88	0.68	0.30	0.38	0.79	80.00	20.00	1.20	4.26	5.00	0.157	11.97
12A 0–20	2.19	2.19	1.50	0.69	2.17	66.67	33.33	2.97	4.89	4.84	0.153	14.29
12Bw 20–68	1.85	0.84	0.40	0.44	1.00	100.0	0.00	1.01	4.74	4.26	0.124	14.92
13A 0–20	5.44	2.66	1.69	0.97	1.74	70.41	29.59	2.78	5.69	5.27	0.575	9.46
13Bw 20–50	2.96	1.22	0.67	0.55	1.22	56.72	43.28	1.74	5.19	4.84	0.304	9.74
14A 0–13	3.57	1.20	0.65	0.55	1.18	86.15	13.85	2.37	5.31	4.58	0.388	9.20
14Bw 13–67	1.47	0.60	0.31	0.29	1.07	100.0	0.00	0.87	4.70	3.98	0.171	8.60
15A 0–10	2.08	0.78	0.40	0.38	1.05	90.00	10.00	1.30	4.92	4.64	0.224	9.29
15Bw 10–60	1.57	0.63	0.38	0.25	1.52	94.74	5.26	0.94	4.63	4.69	0.156	10.06
16A 0–8	2.08	0.56	0.34	0.22	1.54	91.18	8.82	1.52	4.76	4.30	0.100	20.80
16Bw 8–56	1.00	0.25	0.00	0.25	-	0.00	0.00	0.75	-	-	0.052	19.23
17A 0–10	2.43	0.47	0.27	0.20	1.35	100.0	0.00	1.96	4.77	5.34	0.122	19.92
17Bw 10–60	0.68	0.19	0.00	0.19	-	0.00	0.00	0.49	-	-	0.037	18.38

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3. Results and Discussion

The organic carbon content of Cambisols in Vitosha Natural Park can vary widely depending on factors such as the type of forest, soil characteristics, climate, and management. Humus formation takes place under conditions of very high humidity – annual precipitation more than 600 mm, good washing of the soil, mainly in an acidic environment. In connection with this, the parameters of the main humus indicators are formed in the following way: the humus content in the forest variant is highest in the layer located under the forest floor, but it varies greatly depending on the terrain, slope, impurities with undecomposed plant residues and other factors.

The amount of soil organic carbon is high – from 2.08 % to 5.44 % in the surface horizon (tables 1 and 2). Its profile distribution is characterized by a sharp decrease in the cambic horizon, which is typical for soils formed by a forest soil-forming process.

The degree of humification of the organic matter, determined by the percentage of humic acids in the amount of organic C in the A horizon, does not differ significantly between the individual profiles it is almost anywhere above 20 % except in profile 17A horizon, according to Artinova's scale [19].

The type of humus, determined by the ratio between org. C in humic and fulvic acids (Ch/Cf) in the humus-accumulative horizon has different estimates. It is humic type (Ch/Cf > 2) only in 12A and 7A horizon. Humic acid is a dark-colored, high-molecular-weight fraction of humic substances. It is insoluble in water at low pH but becomes soluble at higher pH levels. Humic type improve soil structure, nutrient retention, and cation exchange capacity. The fulvate-humic type of humus predominates – it is established soil horizons: soil profiles 4A, 6A, 6Bw, 7Bw, 9A, 9Bw, 10A, 12A, 12Bw, 13A, 13Bw, 14 and 10. In these soils, the reaction of the soil solution varies within the limits of pH 4.8–6. Humate-fulvate type of humus is found only in 10Bw horizon. Fulvic acid is a lighter-colored, low-molecular-weight fraction of organic substances. It is soluble in water across a wide pH range and has high biological activity.

The content of mobile humic acids – 'free' and associated with sesquioxides reaches up to 100 % in horizons such as 6A, 7Bw, 9A, 9Bw, 12Bw, 14Bw and 17A. In accordance with this fact, humic acids associated with calcium are in low quantity the humus-accumulative horizon due to leaching. Sesquioxides, particularly hematite and goethite, give soil its characteristic as brown color. These compounds also contribute to the soil's ability to retain nutrients and water.

According to Artinova's scale [19] and our results, it can also be estimated that the content of mobile humic acids – 'free' and associated with sesquioxides is very high, in almost all other profiles – vary high and high. Horizons 7A and 13Bw have an average content. In contrast to the above results are those for calcium-bound humic acids. Their amount (percent of the total amount of humic acids) is very low (Table 1).

The unextracted org. C has relatively close values in the individual profiles and varies within the limits of 2.97 % and 0.32 % of the amount of total organic carbon in the A and Bw horizons, the mean value is 15.1 % (Table 2, Fig. 2). Some of this organic carbon is readily extractable using various chemical solvents and methods, a significant portion remains tightly bound to soil particles or exists in forms that are resistant to extraction. This unextracted organic carbon is often referred to as recalcitrant carbon, as it is less susceptible to decomposition and turnover compared to more labile forms of organic carbon. Understanding the dynamics of unextracted organic carbon in soil is crucial for assessing soil fertility, carbon sequestration potential, and the overall health of terrestrial ecosystems. It plays a vital role in soil structure, nutrient cycling, water retention, and climate regulation.

Table 2.
Descriptive statistic of soil organic matter.

Indicator	Total C, %	Total extr. C, %	Ch, %	Cf ,%	Ch/Cf	Unextr. C, %	Total N, %	C/N
Mean	2.37	1.00	0.58	0.41	1.44	1.51	0.21	12.52
St. error	0.26	0.15	0.11	0.05	0.11	0.16	0.03	0.84
Median	2.14	0.79	0.40	0.36	1.49	1.35	0.17	11.27
Mode	1.57	0.84	0.00	0.25	1.74	0.94	N/A	9.29
St. dev.	1.20	0.71	0.50	0.22	0.53	0.76	0.14	3.96
Range	4.88	2.47	1.69	0.80	2.47	2.65	0.54	12.20
min	0.56	0.19	0.00	0.17	0.00	0.32	0.04	8.60
max	5.44	2.66	1.69	0.97	2.47	2.97	0.58	20.80

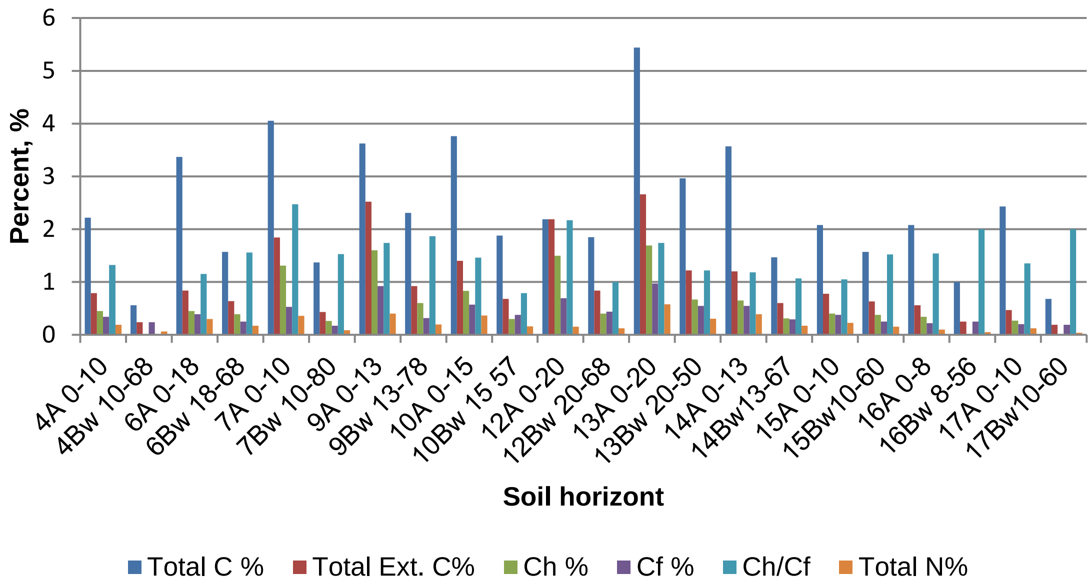

Figure 2.
The composition of soil organic matter.

For all studied soils, the ratio E4/E6 (optical density) is from 3.94 to 5.69, which according to Artinova (2014) [19] is very high to medium and is an indication of humus formation. This takes place in a mountain climate, mainly on low acidic soil-forming materials under the influence of tree vegetation, due to the accelerated process of condensation of humic acids. For Combisols, this process has been proven both in soil formation conditions on carbonate soil-forming rock [27] and on highly acidic soils [28].

The availability and distribution of nitrogen in Cambisols depend on various factors, including climate, vegetation type, soil management practices, and soil texture. Understanding nitrogen dynamics in Cambisols is essential for sustainable sylviculture, as nitrogen is a critical nutrient for plant growth and productivity. The amount in studied of total nitrogen is variating very deeply from 0.04 up to 0.58 %which is from very low to very high. Expectably in surface A horizon the amount of nitrogen is usually to times higher than in cambic Bw horizons. The mean value for all horizons is 0.21 % that means that soils are with average high content of total nitrogen. In Cambisols nitrogen is bound within organic matter, such as dead plant material, microbial biomass, and humus. Organic nitrogen undergoes mineralization, where microorganisms break down organic matter into inorganic nitrogen forms, such as ammonium and nitrate, which are available for trees.

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The Carbon-to-Nitrogen (C/N) ratio is a crucial parameter used to evaluate the quality and decomposition rate of organic matter in soils and humification processes. It represents the ratio of carbon to nitrogen content in a material, often expressed as a mass ratio of particular importance for the rate of decomposition is the nitrogen content in organic residues, which is used by microorganisms for metabolic processes. The organic C:N ratio is used as an indicator of the rate of decomposition of organic matter and biological activity in the soil. For organic horizons, types of humus are Mull, Moder, Mor, Peat, Anmor, Row, etc. [29], but for the conditions of Bulgaria, the more important ones are Mor, Mull and Moder.

In the studied horizons of the soil from the studied sample areas it varies between 8.6 and 20.8 (tables 1 and 2). Most of the soil samples have values C/N > 15 Mull humus is commonly associated with temperate forest ecosystems, where deciduous trees shed their leaves annually, contributing organic matter to the soil. It plays a crucial role in maintaining soil fertility, biodiversity, and ecosystem function in forested environments. The organic matter in *Mull* humus has undergone significant decomposition, resulting in a dark, crumbly, and relatively stable layer of humus. This decomposition process is facilitated by soil organisms such as fungi, bacteria, and earthworms [29].

The Moder type of humus (C/N from 15 to 25) have only horizons 7Bw 15Bw, 16A, 16Bw, 17A 17Bw. This type of humus is commonly associated with temperate and boreal forest ecosystems, where mixed or coniferous trees dominate the vegetation, which could be found in Vitosha Mountain Nature park. Moder humus can vary depending on factors such as parent material, climate, and vegetation type. However, it typically ranges from slightly acidic to neutral. Decomposition of organic matter may release organic acids, influencing soil acidity. Research often provide detailed information on C/N ratios for various soil types and ecosystems, including Cambisols. These ratios can be crucial for understanding nutrient cycling, soil fertility, and ecosystem functioning.

4. Conclusions

The organic matter in Cambisols, it varies depending on factors like parent material, erosion, climate, vegetation, and land use practices. Generally, studied Cambisols contain a moderate to high amount of organic carbon, especially in the topsoil horizon (A horizon). The amount of soil organic carbon is high – from 2.08 % to 5.44 % in the surface horizon. The profile distribution is characterized by a sharp decrease of organic carbon in the cambic horizon, which is typical for soils formed by a forest soil-forming process. The amount of total nitrogen has variation very from 0.04 up to 0.58 %. In surface A horizon the amount of nitrogen is usually two times higher than in cambic Bw horizons as the same as organic carbon. The C/N ratio varies between 8.6 and 20.8. Most of the soil profiles have values C/N > 15 wich is Mull humus. This is commonly associated with temperate forest ecosystems, where deciduous trees shed their leaves annually, contributing organic matter to the soil.

Vitosha Nature park management strategies needs to preserve and enhance soil carbon stocks. Practices such as minimizing soil disturbance, promoting natural regeneration, and reducing erosion can help maintain soil carbon levels and enhance ecosystem resilience in the face of environmental challenges.

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