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Research of Cambisols in Western Balkan Mountains

Biser Hristov*, Kameliya Petrova, Pavel Pavlov, Bilyana Grigorova-Pesheva, Lazar Uzunov

University of Forestry, 10 Kliment Ohridski Blvd., 1797 Sofia, BULGARIA
*Corresponding author: bisseru@abv.bg

Abstract. The research deals with Cambisols soil classification and parameters in the area of Western Balkan Mountains. The studied soils are spread in the Lower altitude area of oak forests (0 to 600 m a.s.l.) and in the Middle mountain area of beech and coniferous forests (600 to 2000 m a.s.l.). The gradient of the slopes varied from flat to steep. The landscape is strongly rugged and covered with forest. The studied Cambisols are formed on granites, granite gneisses, shales, syenites and rhyolites. These soils are characterized by the following features: they have shallow surface horizon A and a deeper B*w cambic* horizon. The horizon sequence of soil profiles is O- A-Bw-CR. Soil pH $_{H2O}$ has mean values of 5.3 in A horizon and decreases in B*w cambic* horizon. The low pH values are result of the leaching of the basic cations in the profile, organic acids washed form soil surface and acidic rocks. Profiles 2, 6 and 7 have base saturation more than 50 %, which defines them as Eutric Cambisols. These soils were identified in the lower parts of the Western Balkan Mountains formed on more basic soil forming rocks. The other soil profiles were classified as *Dystric* Cambisols having base saturation under 50 %. They were developed on more acidic silicate rocks, higher altitude and colder and humid climate of Western Balkan Mountains.

Key words: soil properties, soil classification, Cambisols.

Introduction

Western Balkan Mountain is a part of the Balkan Mountains range ("Stara Planina" in Bulgarian). Geologically, the Balkan Mountains block morphostructure is a complex mosaic of geological structures of different types and ages, composed of weakly metamorphosed, magmatic rocks of Paleozoic age and sedimentary rocks of Mesozoic and Neozoic age. In its heterogeneous structure, the constituent structures are set at different geological times. The modern relief has a relatively massive character, formed on the complex fold structure of the Berkovitsa anticlinorium and the Svoge anticline (Haydutov et al., 1995). Soil-forming rocks are very diverse, Pliocene and Quaternary sediments, poor carbonate and non-carbonate materials, red-brown clays and hard rocks as granites (Zagorchev & Dinkova, 1991). This is a prerequisite for the presence of soils with different chemical composition, properties and base saturation.

Most of Cambisols in Bulgaria are distributed between 800 and 1800 m a.s.l. This altitude range covers most of the Middle mountain area of beech and coniferous forests (600 to 2000 m a.s.l.) also called the middle forest belt. The relief is strongly rugged, and the vegetation is mostly forest, composed mainly of beech

(*Fagus sylvatica* L.), but in the lower part also of oak (*Quercus spp.*), hornbeam (*Carpinus betulus* L.) and birch (*Betula pendula* R.) (Bondev, 2002). The soil-forming rocks on which Cambisols soils are spread are mainly granites, granite gneisses, shales, syenites, rhyolites, etc. (Koinov et al. 1998). Studies by Malinova & Petrova (2019) indicate that unsaturated brown forest soils (*Dystric* Cambisols) predominate in the middle forest belt in the Western Balkan Mountains.

In Bulgaria Cambisols occupy significant areas from 0 - 2000 m a.s.l. mainly in forest areas (Ninov, 2002). In Northern Bulgaria, these soils occupy the foothills and slopes of the Balkan Mountains. For the most part, these are areas with sloping or moderately hilly lowland relief, with characteristic for the oak-hornbeam belt forest, shrubby and grassy vegetation. Cambisols are the main soil type in the mountainous regions, and they are located almost entirely under forest vegetation. They are spread on steep terrains in the higher parts of the mountain areas. Therefore, it is difficult to study their genesis, properties and classification (Bogdanov et al., 2014; Karatoteva et al., 2017; Bogdanov, 2018; Malinova, 2019).

According to Malinova (2016) the soils of Central Balkan Mountains are insufficiently studied. There is a lack of information and data about their accurate classification. It is known that the *Eutric* Cambisols occupy 32.1% of the total Cambisols area in this part of the Balkan Mountains but it is not clearly specified that the remaining area (56.6%) is occupied by *Dystric* Cambisols.

Generally, the mountainous soils in Bulgaria are not well studied. That is why the aim of the research is to establish the main morphological, chemical and physical processes and properties of Cambisols, which are the main soil type in Western Balkan Mountains.

Materials and Methods

Profiles with numbers 1, 2, 3, 4, 5, 6 and 7 were studied and described with the following features: location, altitude, slope, parent rocks, vegetation and land use. Morphologically the soil profiles were described according to the guidelines for soil description (Jahn et al., 2006).

The soil characteristics were analyzed according to the following methods: organic carbon (org. C, %) by the modified Turin´s method (Kononova, 1963; Filcheva & Tsadilas, 2002); total nitrogen (total N, %) content, with a modified version of the classic Kjeldahl´s method with Kjeltec Auto 1030 Analyzer; soil acidity (pH_{H2O}; pH_{CaCl2}) – measured potentiometrically with WTW 720 pH meter (ISO 10390); soil texture (sand - 2 mm - 63 µm, %; silt - 63 µm - 2 µm, %; clay < 2 µm, %), using the sedimentation method (ISO 11277:2009); C/N ratio – calculation method; exchangeable acidity (extraction of 0.1 mol/l solution of $BaCl_2$) and exch. Ca, exch. Mg, and exch. K (ISO 11260&14254); Microsoft Office 10 for graphs, statistics and tables.

Results and Discussion

The main soil properties of Cambisols are presented in Table 1.

Cambisols can be found in all regions of Bulgaria, but usually these soils are spared in hilly and mountainous sloppy areas under forest. They have surface soil horizon, which is lighter in color, especially in leached soils where it is usually brownish or yellowish (Fig. 1).

The studied soils were characterized by the following features: they have shallow surface horizon A and a deeper B*w cambic* horizon. Surface A horizon varies from 1 cm to 22 cm depth, but mean values is 7.8 cm. The horizon sequence of the soil profile is O-A-B*w*-CR.

The most important horizon of these soils is subsurface *cambic* horizon (B*w*). According to WRB (IUSS Working Group, 2015), the pedogenetic alteration of a *cambic* horizon can also be established by contrast with one of the overlying mineral horizons that are generally richer in organic matter and therefore have a darker and less intense colour. These features can be seen in Fig. 1, with darker surface A horizon and alternation in subsurface B*w* horizon.

Table 1. Main soil properties of Cambisols.

Horizon/ Layer	Depth cm	Sand >0.063 mm	Silt 0.063 -0.002 mm	Clay <0.002 mm	Org. C %	Total N %	C/N	pH_{H2O}
Profile 1. *Dystric* Cambisols Loamic								
O	2-0	-	-	-	26.66	1.487	10.40	5.2
A	0-6	48.85	25.21	25.93	4.46	0.270	9.58	4.6
Bw1	6-30	49.14	25.57	25.29	4.00	0.243	9.55	4.3
Bw2	30-45	48.13	25.40	26.47	2.39	0.166	8.35	4.4
Profile 2. *Eutric* Cambisols Loamic								
O	1-0	-	-	-	31.53	1.3	14.08	5.4
A	0-5	58.98	22.95	18.07	7.52	0.38	11.60	6.0
Bw	5-20	56.25	23.92	19.83	2.04	0.10	11.38	4.7
C	20-47	-	-	-	0.81	0.01	52.20	4.9
Profile 3. *Dystric* Cambisols Loamic								
O	1-0	-	-	-	33.46	2.02	9.60	5.1
A	0-4	51.23	28.83	19.94	6.35	0.34	10.90	4.8
Bw1	4-30	40.62	39.33	20.05	2.39	0.12	11.55	4.5
BC1	30-41	41.52	49.58	8.90	0.76	0.04	11.91	4.4
BC2	41-↓	64.12	29.46	6.43	0.65	0.03	15.08	4.6
Profile 4. *Dystric* Cambisols Loamic								
O	1-0	-	-	-	32.84	1.89	10.09	5.0
A	0-1	52.41	28.13	19.46	3.95	0.21	10.96	4.9
ABw	1-10	47.93	30.62	21.45	1.54	0.11	7.98	4.2
Bw	10-34	47.21	31.43	21.37	1.74	0.09	11.73	4.2
BC	34-55↓	52.06	28.3	19.64	1.13	0.06	10.40	4.3
Profile 5. *Dystric* Cambisols Loamic								
O	2-1	-	-	-	33.77	1.83	10.72	5.2
OH	1-0	-	-	-	15.58	1.39	6.49	5.3
A	0-4	75.09	16.52	8.40	2.52	0.19	7.61	4.4
Bw1	4-23	61.46	27.02	11.51	1.62	0.14	6.66	4.5
Bw2	23-32	63.68	29.06	7.26	0.62	0.09	3.95	4.6
BC	32-70↓	67.85	23.43	8.72	0.25	0.04	3.63	5.1
Profile 6. *Eutric* Cambisols Loamic								
O	1-0	-	-	-	35.21	1.46	13.99	5.8
A	0-10	40.86	36.57	22.56	2.37	0.20	6.80	5.1
Bw1	10-18	38.25	38.16	23.6	1.41	0.13	6.10	4.6
Bw2	18-30	39.98	35.57	24.45	0.88	0.12	4.29	4.8
BC	30-110↓	51.9	24.8	23.3	0.18	0.08	1.39	5.7
Profile 7. *Eutric* Cambisols Loamic								
A	0-4	50.02	27.6	22.38	3.4	0.32	6.26	6.7
Bw1	4-17	53.49	26.41	20.11	2.61	0.28	5.50	5.6
Bw2	17-31	51.67	25.93	22.4	1.5	0.17	5.15	5.7
BC	31-53	48.47	25.36	26.18	0.64	0.10	3.83	5.6
C	53-↓	-	-	-	0.19	0.08	1.38	5.3

Fig. 1. Profile 2 (left) and Profile 3 (right) –
typical shallow Cambisols in Western Balkan Mountains.

The other diagnostic criteria for the definition of cambic horizon are, 15 cm deep and more, soil texture of sandy loam or finer. Similar properties can be seen in all soil profiles (Table 1). The soil texture was assessed as sandy loam, loam and sandy clay loam (Fig. 2). That defines all soil profiles as Loamic according to the second level qualifiers in WRB (IUSS Working Group, 2015).

Soil texture varied in a wide range mainly depending on the soil-forming materials. Cambisols are characterized by low clay content and significant number of skeletal elements the amount of which increases in depth.

Studied soils are characterized by high organic carbon content, about 4.5% in mineral A horizons, the reason for relatively high content is that these soils are developed under the influence of forest vegetation and they never have been cultivated. In the Bw horizons the humus decreases to the average value of 2.44% (Table 1 and Fig.3). The highest values of soil organic matter are in surface organic (O) layers. These soil layers are dominated by organic materials consisting of undecomposed or partially decomposed litter formed by the litterfall of the trees.

The C/N ratio in more of the soil horizons is under 15, which means that the type of humus is *mull* with mean value of 9.7. According to Vanmechelen et al. (1997) in South Europe there is advanced degree of transformation of organic matter and formation of stable humic substances. *Mull* humus is characterized by a fast turnover rate and an intimate mixture with mineral soil materials, and it is the most frequently observed humus type in Bulgaria. The *mull* type often consists fresh, undecomposed leaves, while older organic materials have already been incorporated in the mineral soil. In the metamorphic (B*w*) horizons the ratio decreases.

The amount of total nitrogen in Cambisols formed under the influence of forest vegetation is very dynamic indicator depending on the amount of moisture in the soil in different seasons and conditions of the processes of ammonification and nitrification. The content of total nitrogen in the soil follows the same trend as carbon with values from 0.01 up to 0.38 %.

The soil pH_{H2O} in *A* horizon varied between 6.7 (profile 7) and 4.2 (profile 4) - In subsurface B*w* horizon the pH is low and reaches the lowest obtained values. The soil reaction in the studied Cambisols was assessed as neutral to strongly acid. The low values indicated that there is ongoing destructive process of exchangeable Al over the soil mineral compositions. Its quantity is not high due to the low value of the cation exchange capacity (CEC). The low pH values are result of the leaching of the basic cations in the profiles.

The acidity of the studied profiles increases in *cambic* horizons, due to the vertical migration of acidic products from the soil formation process, including free organic acids. This defines it as more acidic than the surface A horizon. The soil acidity of soils is a result of silicate soil-forming rocks and organic residues. The exchangeable acidity varied (exch. Al) form 0.2 – 5 cmol(+).kg^{-1}. Highest values of exch. Al were assessed in B*w cambic* horizon (Table 2). These soil profiles (1, 2, 3, 4 and 5) were defined as *Dystric* Cambisols. Therefore, basic cations such as exch. Ca, exch. Mg, and exch. K have higher values in the *Eutric* Cambisols (profiles 2, 6 and 7). Results showed that calcium cations have highest values in comparison to the magnesium and potassium cations.

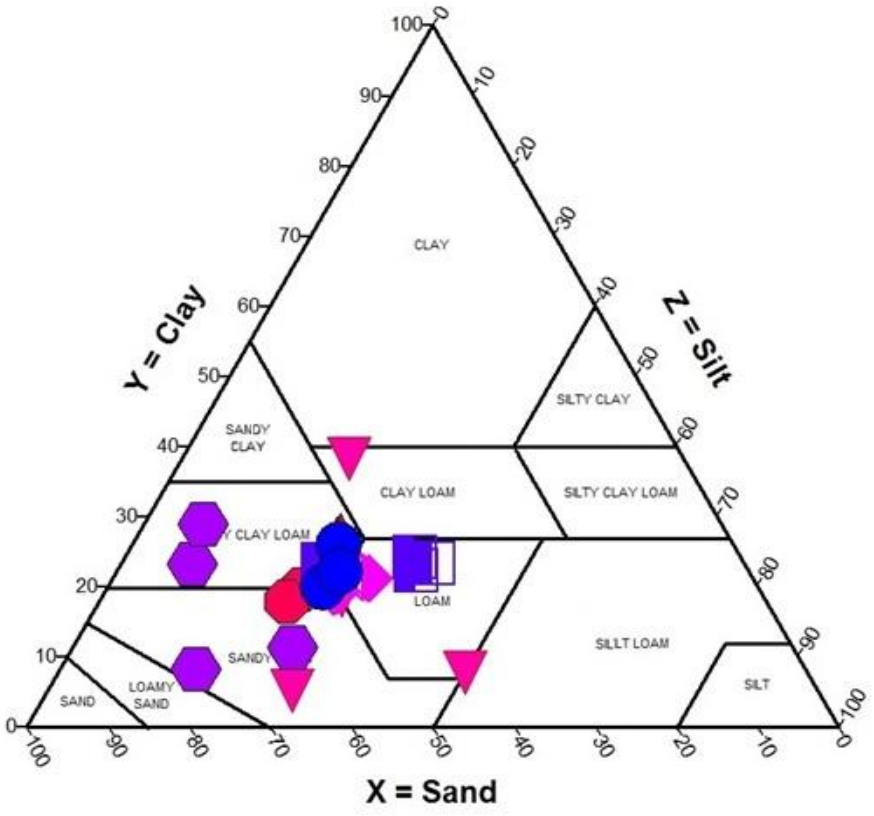

Fig. 2. Soil texture triangle with textural classes. (Profile 1 pink diamonds, Profile 2 red triangle, Profile 3 in pink triangles, Profile 4 red hexagon, Profile 5 in purple hexagon, , Profile 6 in purple square, Profile 7 in blue circle).

Table 2. Physicochemical values of Cambisols.

Horizon/ Layer	Depth cm	pH $_{CaCl2}$	Exch. Al	Exch. Ca	Exch. K	Exch. Mg	CEC	BS %
			cmol(+).kg^{-1}					
Profile 1. *Dystric* Cambisols Loamic								
O	2-0	4.9	1.00	28.85	1.16	4.71	39.18	97
A	0-6	3.9	2.73	1.74	0.12	0.28	4.98	44
Bw1	6-30	3.8	3.45	0.93	0.02	0.14	4.63	24
Bw2	30-45	3.9	2.82	0.79	0.00	0.11	3.90	24
Profile 2. *Eutric* Cambisols Loamic								
O	1-0	4.6	0.73	40.77	2.41	4.71	53.38	98
A	0-5	5.4	0.64	17.59	0.00	3.53	22.44	97
Bw	5-20	4.1	5.00	7.69	0.03	2.61	15.75	67
C	19-47	4.6	0.55	13.03	0.03	3.33	17.36	97
Profile 3. *Dystric* Cambisols Loamic								
O	1-0	4.8	1.00	36.99	2.32	8.34	53.71	98
A	0-4	4.2	1.27	3.75	0.25	1.12	6.54	80
Bw1	4-30	4.1	2.27	0.50	0.04	0.34	3.20	28
BC1	30-41	4.0	1.91	0.94	0.00	0.67	3.59	46
BC2	41-80	4.0	1.09	0.53	0.01	0.33	1.98	45
Profile 4. *Dystric* Cambisols Loamic								
O	1-0	4.8	1.36	35.77	1.57	10.39	54.43	97
A	0-1	4.3	1.73	1.85	0.40	0.98	5.06	65
ABw	1-10	3.8	3.09	0.60	0.05	0.37	4.18	25
Bw	10-34	3.8	2.82	0.21	0.01	0.12	3.19	11
BC	34-55	3.7	3.27	0.34	0.00	0.19	3.86	14
Profile 5. *Dystric* Cambisol Loamic								
O	2-1	4.6	1.09	40.45	1.13	6.90	55.27	98
OH	1-0	4.6	0.55	29.59	0.41	3.05	36.01	98
A	0-4	3.7	2.36	1.12	0.10	0.21	3.84	38
Bw1	4-23	3.9	2.00	0.25	0.01	0.07	2.36	14
Bw2	23-32	3.9	1.36	0.40	0.02	0.08	1.87	27
BC	32-70	4.2	0.55	0.94	0.00	0.24	1.74	68
Profile 6. Eutric Cambisols Loamic								
O	1-0	5.2	0.64	35.13	1.61	10.12	52.49	99
A	0-10	4.5	0.64	7.82	0.26	1.73	10.68	94
Bw1	10-18	4.0	1.45	6.11	0.13	1.65	9.54	84
Bw2	18-30	4.2	0.73	7.35	0.10	2.01	10.41	93
BC	30-110	5.3	0.27	10.71	0.11	4.76	16.51	98
Profile 7. *Eutric* Cambisols Loamic								
A	0-4	6.3	0.18	16.42	0.35	2.01	19.43	99
Bw1	4-17	5.0	0.45	10.30	0.07	1.05	12.10	96
Bw2	17-31	5.2	0.27	10.01	0.02	0.68	11.19	98
BC	31-53	4.7	0.45	11.45	0.03	0.86	13.08	96
C	53-80	4.3	0.64	12.42	0.03	1.08	14.60	95

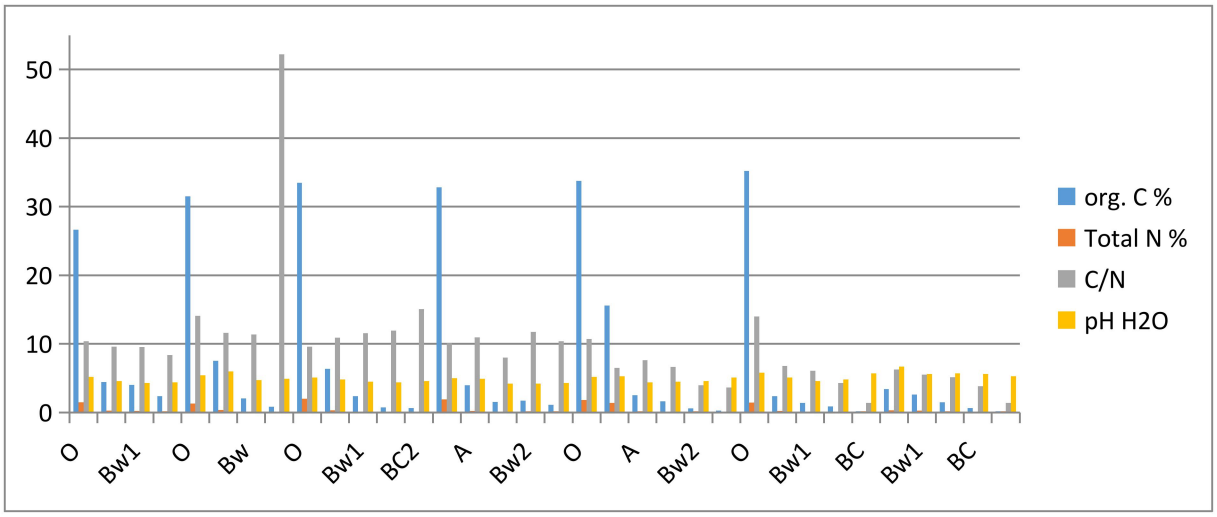

Fig. 3. Main chemical properties – org. C %, Total N %, C/N, pH_{H2O}.

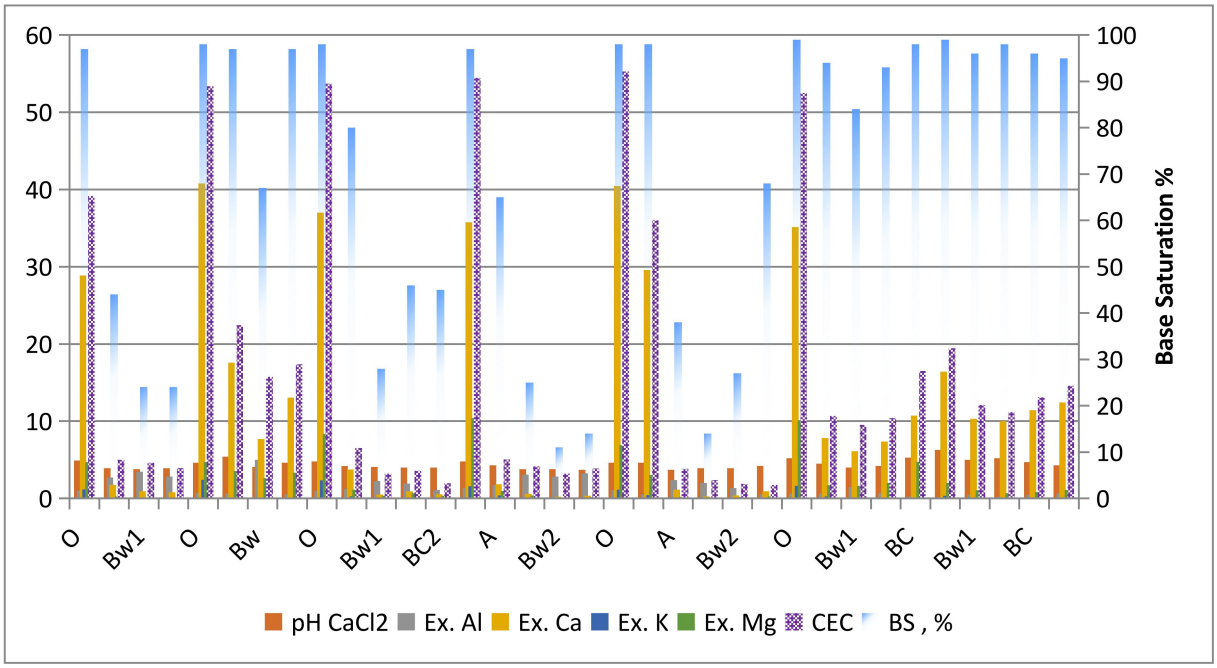

Fig. 4. Base Saturation and physicochemical properties of Cambisols.

According to Ganev (1989) the acidic instability of clay minerals is determined by the soil colloids which are in the state of incomplete neutralization with basic cations. In *Dystric* Cambisols the destructive processes (high soil acidity and exch. Al) have negative effect on clay colloids formation. Quantity of basic cations is also low in the C horizons and in litterfall (O horizon). Therefore, the acidification is a naturally occurring process.

The results indicated that CEC decreased with the progress of the soil acidification. The CEC is usually low with mean value about 8 cmol(+).kg^{-1} (from 2.3 up to 27.6 cmol(+).kg^{-1} in the mineral horizons). In organic (O) layers, it was very high and varied from 19 up to 54 cmol(+).kg^{-1}.

The base saturation (BS) is one of the main chemical properties used for soil classification. The sum of basic exchange cations (exch. Ca, exch. Mg, exch. K) define the degree of base saturation. It is typical for all organic layers to have high base saturation and the studied ones are not an exception (table 2 and fig.4). Profiles 2, 6 and 7 have base saturation in *cambic* diagnostic horizon (B*w*) over 50 %, which defines them as *Eutric* Cambisols according WRB (IUSS Working Group, 2015). *Eutric* Cambisols in the studied area were spread in the lower parts of the Western Balkan Mountains. They were formed on more basic soil forming rocks with favorable soil properties and moderate fertility.

The other soil profiles were classified as *Dystric* Cambisols, because they had base saturation under 50 % in *cambic* horizon. These soils are developed on more acidic silicate rocks with higher altitude in colder and humid parts of the Western Balkan Mountains. *Dystric* Cambisols have low fertility and in most of the cases they are threaten by degradation and erosion.

Conclusions

Cambisols are the main soil type in Western Balkan Mountains developed on silicate rocks mainly granites, granite gneisses, shales, syenites, rhyolites. The horizon sequence of soil profile is mainly O-A-Bw-CR, with shallow surface organic layers and mineral horizons and deeper *cambic* horizons.

Soil texture differs depending on the soil-forming materials. It varied between sandy loam, loam and sandy clay loam. Cambisols have low clay content and higher number of skeletal fragments.

Soils are characterized by relatively high organic carbon content of 4.5% in the surface A horizon, but in B*w* horizon it decreases nearly twice. The mean value of calculated C/N ratio is 9.7. Therefore, the type of humus is *mull* in almost all of the studied profiles.

The studied Cambisols have neutral to strongly acidic reaction (pH $_{H2O}$). There is ongoing destructive process due to the impact of exchangeable aluminum on the secondary minerals of the soil. Soil acidity increased in *cambic* horizons. The obtained lower pH values were due to the released acidic products in soil from weathering rocks, free organic acids leached from the soil surface and low quantities of basic soil cations.

Profiles 2, 6 and 7 were classified as *Eutric* Cambisols (Loamic) because they have base saturation over 50 % in *cambic* horizon and loamic soil textural qualifier. Profiles 1, 3, 4, 5 were identified as *Dystric* Cambisols (Loamic) because their base saturation is under 50 % in *cambic* diagnostic horizon.

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