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The Arenosols of Western Rhodopes Mountain (Bulgaria)

Biser Hristov[1,2], Ivaylo Kirilov[2*]

[1] - University of Forestry, Faculty of Forestry, 10 Kliment Ohridski Blvd., 1797 Sofia, BULGARIA

[2] - ISSAPP "N. Poushkarov", Department of Soil Genesis, Diagnostic and Soil Classification, 7 Shose Bankya, 1331, Sofia, BULGARIA

*Corresponding author: stingra@abv.bg

Abstract. The Arenosols of Western Rhodopes Mountain are spread on soft, unconsolidated Neogene and Quateranry modern sediments with a sandy texture and weak structure. New research on their genesis, properties, diagnosis and classification were made on their major diagnostic features. Arenosols profile is typical A–AC–C type with low humus content and relatively lower values of CEC compared with other sandy soils in Bulgaria. Content of the soil particles of sandy fraction is above 80 % and soil texture is sandy or loamy sandy, which is main diagnostic feature for Arenosols classification. The research confirms the criteria for their terrain recognition and new additional data for mountainous sandy soils were established.

Key words: soil classification, soil texture, CEC, base saturation.

Introduction

In the western Rhodopes Mountain, in a complex with Cambisols, Umbriosls or Lepthosols, there are areas filled with sandy sediments from weathered rocks, on which sandy soils known as Arenosols can be found (IUSS working group, 2014). It is well known fact that sandy soils are spread in Bulgaria, on the Black Sea coast and around Danube River (Kirilov, 2013; Kachova, 2020). Similar soils can be found in the interior parts on terraces with old and modern sediments with different geological age, sandy, unconsolidated, loose and soft rocks (Zagorchev et al., 1991).

The area of Rhodopes Mountain has typical for Europe temperate-mountainous climate. It is characterized by a relatively higher amount of precipitation (700-900 mm per year), high atmospheric humidity, small temperature amplitude, availability of a stable and relatively thick snow cover (Subev et al., 1960).

The forest vegetation is represented by coniferous, mixed beech-coniferous and beech forests with an admixture of hornbeam, oak, linden, aspen, hazel, etc. (Bondev, 1990; Ferezliev et al., 2019). The vegetation up to 1200 m is represented by beech (in places around the lower limit of the forest belt - 700-800 m). The variety of vegetation has a significant influence on the processes of organic matter formation, accumulation and type of the humus.

The studied research area falls into the Western Rhodope Mountain (Fig. 1). The geological material is made up of, igneous, metamorphic and sedimentary rocks (Fig. 2). The soil-forming rocks from which the sandy soils were formed are mainly weathered granites, granitogneisses, slates, syenites, rhyolites, sandy shale, sandstone, etc. (Gerasimov et al., 1960; Geography of Bulgaria, 2002).

The studied soils occupy the places geologically covered with Neogene and Quaternary sands in the area of the western part of Chepinska Valley and the town of Velingrad (Fig. 2). The Chepin basin is an intermountain basin in the northwestern part of the Western Rhodopes, known as the Chepinska valley, which is the largest valley in the Rhodopes Mountain.

The basin was formed during the Tertiary - Pliocene, as a result of tectonic subsidence along faults, after which it was filled with Pliocene lake sediments (Fig. 2). Soils developed on Neogene and Quaternary sands occur almost exclusively on the banks and valleys where these sands are exposed (Krastanov et al., 2018).

They are shallow and poor in organic matter because they are well washed. The terrain is highly rugged, with large slopes. Arenosols genesis, diagnostics, formation processes, microbiological characteristics, sorption capacity, are well studied in the other low parts of Bulgaria (Kirilov et al., 2011; Kirilov, 2013; Teoharov et al., 2019).

The main purpose of our research is to describe and classify the soils on Neogene and Quaternary sand deposits, to define and determine their properties and indicators in order to describe the process of soil formation on these newly formed sediments.

Materials and Methods

To establish the criteria and diagnostics for the recognition of sandy soils - Arenosols in this article we use data from studies in the area of Western Rhodopes mountain, in the western area of the town of Velingrad and in the nearest Chepinksa valley (Fig. 1). In addition to in-depth geomorphological and morphological studies, analytical results are given by various diagnostic indicators.

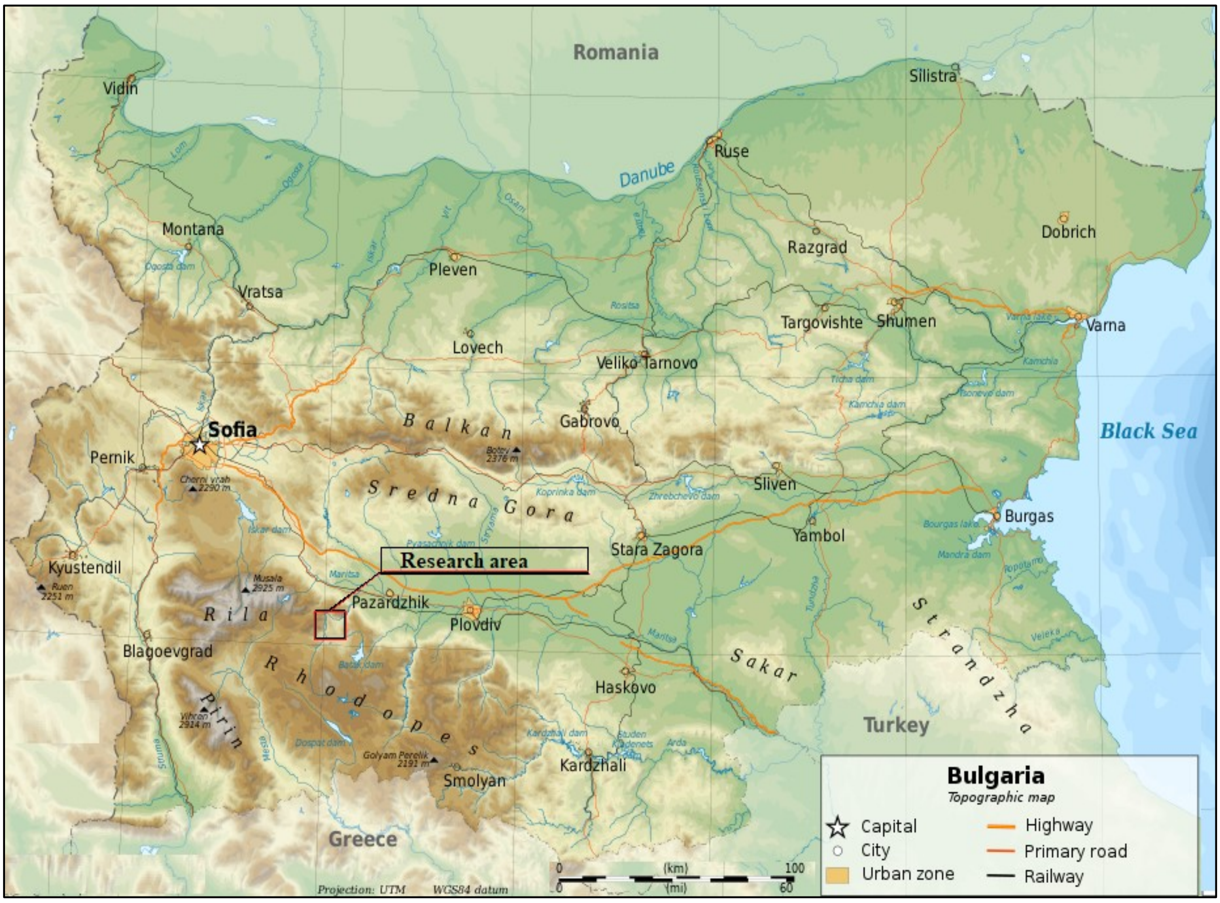

Fig. 1. Geographic map of Bulgaria (2009) with selected research area.

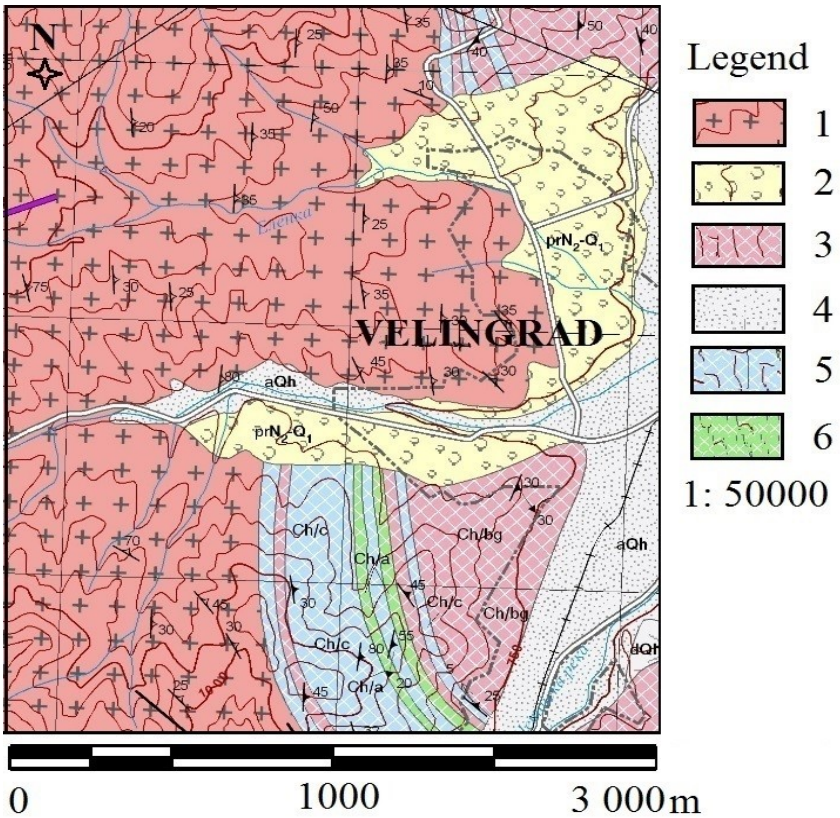

Fig. 2. Geological map of the area of Velingrad town (Sarov et al., 2009; part of the map). Legend: 1 - Granites; 2 - Neogene-quaternary gravels and sands; 3 - Biotite gneiss, amphibole-biotite gneiss; 4 - Quaternary sands and gravels; 5 - Marbles; 6 - Amphibolites.

Five soil profiles were studied in the different parts of the Rhodopes mountain. First three soil profiles are in the western part of the town of Velingrad and the other two profiles are in the lower parts of the Chepinksa valley in Rhodopes mountain.

The analysis of soil samples was performed according to the following indicators, criteria and methods: 1) Morphological description of soil horizons and characteristics (Guidelines for soil description, Jahn, et al., 2006); 2) Soil texture by Kachniski (1958), transformed to USDA classes (Soil Science Division Staff, 2017); 3) Total carbon content according to Tyurin (Kononova, 1966); 4) Total nitrogen content according to Keldal (Penkov et al., 1991); 5) Cation exchange capacity (CEC), total acidity (H8.2), exchange cations (Ca, Mg, Al) and degree of bases saturation BS % (Ganev et al., 1980); 6) pH in water was measured potentiometrically with "WTW 720" pH meter. Microsoft Excel 2010 was used for graphical visualization and statistics calculations. Dplot (2017) program was used for soil texture triangle presentation.

Studied Arenosols in the Western Rhodopes Mountain (Fig. 3) can be classified as: profile 1 - Dystrict Arenosol Colluvic; profile 2 - Dystrict Arenosol Colluvic Raptic; profile 3 - Eutric Arenosol Colluvic Ochric; profile 4 - Eutric Arenosl Colluvic; profile 5 - Dystrict Arenosol Colluvic Raptic (IUSS working group, 2014).

Results and Discussion

The peculiarities of the field studies show that the sandy soils in the Western Rhodopes mountain are spread over flat, gently sloping surfaces. They have a primitive structure of the soil profile and its horizons: A(AC) – AC – C. The depth of the profile (A+C) is often about 30-120 cm and rarely above this limit. The depth of the soil profile indicates that these soils are weak depeloped, because A horizons are too shallow and C horizons are unconsolidated parent material (Fig. 3 and Fig. 4).

Fig. 3. The profiles 1 and 4 of Arenosols in the Western Rhodopes mountain.

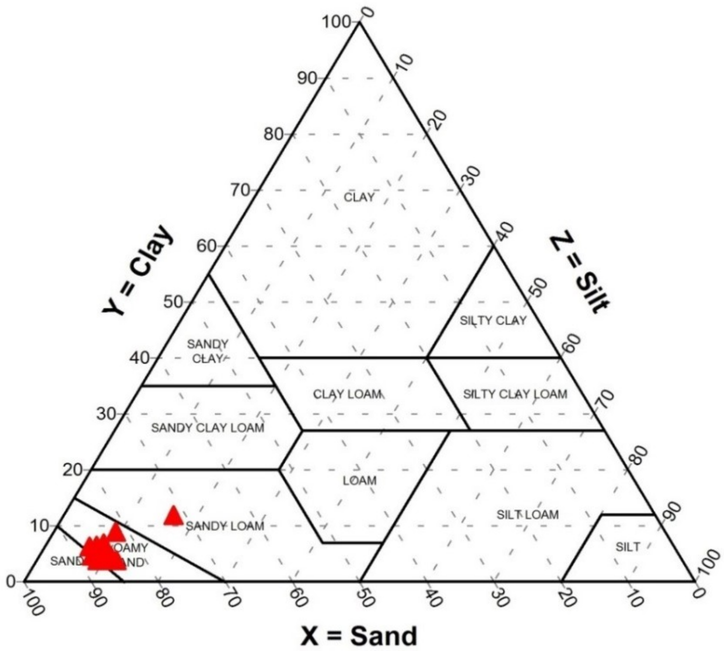

Fig. 4. Soil texture of the soil horizons - USDA texture classes (Soil Science Division Staff, 2017)

The color of deeper soils can be from light brown to yellowish. Sandy and mountainous soil profiles have a very shallow surface A horizon of about 3 cm to 7 cm, and it is characterized by a loose and sandy structure or is unstructured. The lower horizons usually represent weathered particles, mainly sand. These are weathered C horizons that is slightly sandy without structure.

The surface (A) horizon in these studied parts of the area is in the initial stage of development under the influence of organic residues and partly grass vegetation. The content of organic carbon is in very wide range from 0.18 up to 9%. The high content is due to mixture of forest litter in the soil surface. Over 60% of the amount of carbon is found in A horizon. These soils have low moisture capacity and good water permeability. In the profiles with a higher content of organic matter in the surface horizon, even a few centimeters of dead, semi-decomposed or decomposed organic horizon is observed, which leads to an increase of organic carbon and the influence of the specific temperature and water regime in the sub-mountainous climatic region.

The nitrogen content is closely dependent on the amount of humus in the soil and it changes depending on the conditions of the soil-forming process and the degree of soil humification. Its total content in the soil depends on the content of organic substances that are decomposed from the plants, microbial biomass and the soil fauna (Mitovska, 1989). The amount of total nitrogen in the surface horizon varies from a very small quantities from 0.08% up to 0.48% in the surface horizons rich of forest litter, but it is low as a whole.

The degree of decomposition of soil organic matter is a ratio of the amount of carbon, to the amount of total nitrogen in the soil or the C:N ratio. The results of the C:N ratio show that the values aren't close and they vary from 12.9 to 41.8, i.e. from very narrow to ultra wide ratio (Table 1). In most profiles this ratio is between 12 and 32 wide, therefore the type of humus is of the following three types - Mull, Moder and Mor (Kononova, 1966). Soil profiles 1 and 2 are under pine forest that is way the type of the humus is Mor. The profile 4 is under grass vegetation in the lower parts of the Chepinska valley where the type of humus is Mull. Other soil profiles have Mor or Moder type. The mobility of humic acids favors the process of podsolization. From the analysis, it can be concluded that the C:N ratio and the type of humus vary widely in the studied soils. In mountainous regions, it is characteristic that the type of humus is more acidic - Mor or Moder. Here the processes of decomposition of organic matter are delayed because of mountainous climatic conditions. Nitrogen values are too low in these soils, so this dependence can hardly be calculated.

Table 1. Main soil diagnostic properties of Arenosols from Rhodopes mountain (Bulgaria)

Num.	Horizon, Depth/cm	pH (H_2O)	Total Org. C %	Total N %	C/N	Sand >0.05 mm %	Silt 0.05-0.002 mm %	Clay <0.002 mm %
Profile 1. Dystrict Arenosol Colluvic								
1	A 0 – 3	5.9	9.34	0.45	20.8	85.6	10.6	3.8
2	C1 3 – 30	5.5	0.46	0.03	23.2	85.7	10.5	3.8
3	C2 30 – 70	4.8	0.48	0.02	24.1	86.2	7.8	6
4	C3 70 – 100	4.8	0.48	0.02	24.1	87.8	8.0	4.2
Profile 2. Dystrict Arenosol Colluvic Raptic								
5	A 0 – 3	5.6	5.22	0.19	27.6	87.3	9.3	3.4
6	C 3 – 27	4.4	1.13	0.03	37.5	87.0	9.2	3.8
Profile 3. Eutric Arenosol Colluvic Ochric								
7	A 0 – 2	5.6	2.91	0.17	17.1	86.6	8.85	4.55
8	C1 2–40	4.4	0.27	0.02	13.6	82.1	8.45	8.45
9	C2 40 – 80	4.9	0.18	0.01	18.0	84.9	8.7	6.4
10	C3 80 – 120	4.9	0.42	0.01	41.8	87.3	6.9	5.8
Profile 4. Eutric Arenosol Colluvic Ochric								
11	AC 0 – 24	4.9	0.77	0.06	12.9	82.1	9.2	8.4
12	C1 24 – 70	5.8	0.57	0.04	14.2	72.0	16.55	11.45
Profile 5. Dystrict Arenosol Colluvic Raptic								
13	Ah 0 – 7	5.6	2.49	0.08	31.1	84.5	12.1	3.4
14	C1 7 – 20	5.6	1.21	0.04	30.2	85.0	10.9	4.1
15	C2 20 – 40	5.5	0.84	0.03	27.8	86.9	9.1	4.0

The sandy fraction in these soils completely dominates and reaches very high values, with the average value being about 84%. In the studied profiles, this fraction varies from 72% to 87.8% (Table 1). This is solid evidence for the influence of the parent rock on the sandy fraction, as it generally increases in the C horizon. The main diagnostic indicator remains the sandy fraction, which is over 80% and is the average texture class of loamy sand or sand (Fig. 4). In most cases, they also contain gravel in their soil profile. The present results confirm other earlier studies, which show that the sandy fraction is used as a diagnostic indicator and it is confirmed as a value above 80% sand content for classifying sandy soils in Bulgaria (IUSS working group, 2014; Teoharov et al., 2019).

The reaction of soils is essential for internal soil processes and the level of soil fertility. The soil acidity depends mostly on the soil-forming rock, the vegetation can vary widely. The main components that determine the reaction of the soils from the studied lands are exchangeable H^+, Al^{3+}, Ca^{2+} and Mg^{2+}. The sands contain mainly quartz, therefore the sorption capacity is low (Table 2).

It has been established that in forest soils, hydrogen (H^+) and hydrolytic acid aluminum (Al^{3+}) ions take a more significant part in the composition of exchangeable cations. Our research shows a low degree of saturation with alkaline earth bases Ca and Mg. (Table 2 and Table 3). The exchangeable Ca^{2+} is between 5 to 16 mequ/100g soil and the exchangeable Mg^{2+} is about which is low, because of the weathered silicate sandy rocks on which Arenosols are formed.

An average exchangeable acidity is observed (ex. H8.2 forms 7 – 12 mequ/100g soil) and low values of exchangeable aluminum (ex. Al forms 0.5. up to 2.0 mequ/100g soil) are found in the profiles, due to the acidic vegetation and lack of carbonates (Fig. 5).

Table 2. Main physicochemical properties of studied Arenosols from Western Rhodopes Mountain (Bulgaria) – CEC, exchangeable cations and base saturation.

	Horizon/depth cm	CEC	Ex H8.2	Ex Al	Ex Sa	Ex. Mg	Base Saturation, %
		mequ/100g soil					
Profile 1. Dystrict Arenosol Colluvic							
1	Ah 0 – 3	30.7	12.5	0.8	16.4	1.0	58.19
2	C1 3 – 30	16.8	8.0	1.0	7.0	0.8	55.56
3	C2 30 – 70	15.7	8.4	1.4	5.1	0.8	42.07
4	C3 70 – 100	15.8	8.6	1.4	5.0	0.8	40.69
Profile 2. Dystrict Arenosol Colluvic Raptic							
5	Ah 0 – 3	21.6	9.0	1.1	10.6	0.9	56.10
6	C 3 – 27	19.0	9.6	2.6	6.0	0.8	41.82
Profile 3. Eutric Arenosol Colluvic Ochric							
7	Ah 0 – 2	21.0	8.0	1.2	10.8	1.0	59.80
8	C1 2–40	19.4	9.6	2.5	6.5	0.8	43.53
9	C2 40 – 80	20.2	8.4	2.0	8.9	0.9	53.85
10	C3 80 – 120	19.4	8.4	1.6	8.5	0.9	52.81
Profile 4. Eutric Arenosol Colluvic Ochric							
11	AC 0 – 24	20.8	8.5	1.7	9.8	0.8	55.50
12	C1 24 – 70	21.0	7.0	0.5	12.5	1.0	65.85
Profile 5. Dystrict Arenosol Colluvic Raptic							
13	Ah 0 – 7	19.3	8.6	1.2	8.5	1.0	52.75
14	C1 7 – 20	18.5	8.8	1.0	7.9	0.8	49.71
15	C2 20 – 40	18.3	9.0	1.3	7.2	0.8	47.67

Although the soils are spared on sands of different geological ages, these profiles have largely similar physicochemical properties. In terms of content, quartz is the dominant mineral in all profiles and horizons, and this determines the primary nature of the soil-forming process. Quartz is very resistant to weathering, and this resistance has provided it with a quantitative predominance which has a relative increase in the surface horizon.

The studied soil profiles have an average base saturation of 51% (Table 2 and 3, Fig. 5). There are saturated Eutric horizons (B.S. > 50%) and also unsaturated Dystric horizons (B.S. < 50%). Profiles 3 and 4 can be defined as Eutric Arenosols. Profiles 1, 2 and 5 are classified as Dystric Arenosols because they are mostly unsaturated with bases.

Table 3. Descriptive statistics of the studied soil chemical properties.

Statistics Values	pH (H_2O)	Total C %	Total N %	CEC	Ex H8.2	Ex. Al^{3+}	Ex. Ca^{2+}	Ex. Mg^{2+}	BS %
Mean	5.31	1.89	0.08	19.83	8.83	1.42	8.71	0.87	51.73
St. Error	0.15	0.77	0.03	0.91	0.31	0.15	0.78	0.02	1.91
Median	5.50	0.80	0.03	19.40	8.60	1.30	8.50	0.80	52.81
Mode	5.60	#N/A	0.03	21.00	8.40	1.00	8.50	0.80	#N/A
St. Dev.	0.57	2.97	0.12	3.52	1.20	0.59	3.02	0.09	7.38
Range	1.70	11.62	0.44	15.00	5.50	2.10	11.40	0.20	25.16
Minimum	4.40	0.18	0.01	15.70	7.00	0.50	5.00	0.80	40.69
Maximum	6.10	11.80	0.45	30.70	12.50	2.60	16.40	1.00	65.85

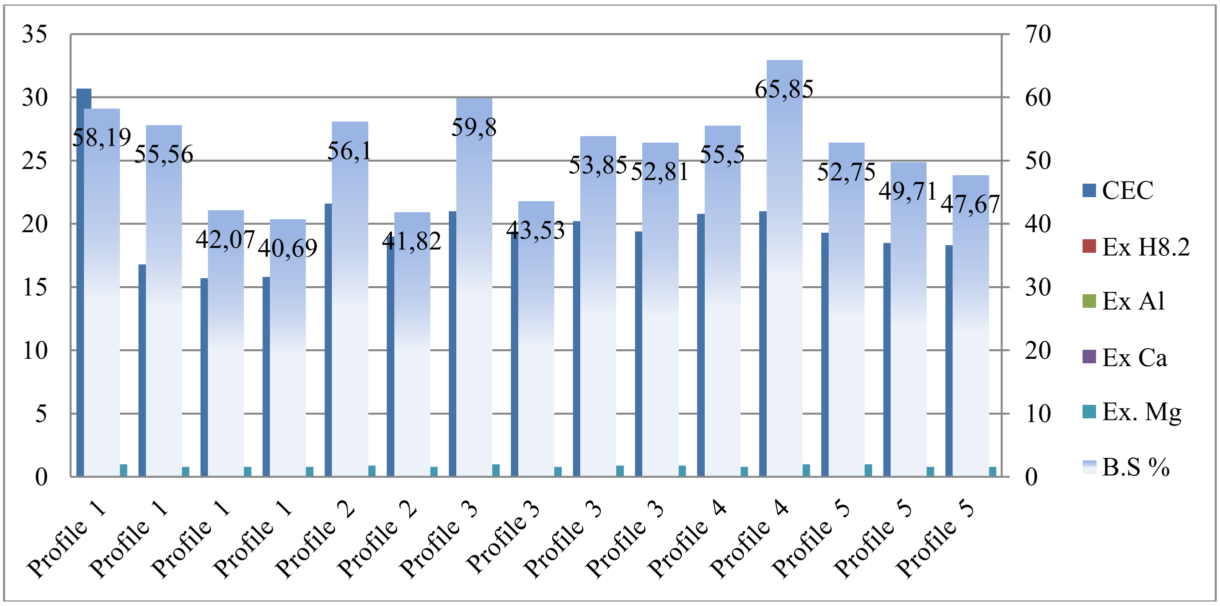

Fig. 5. Physicochemical indexes - CEC, ex. Al, ex H8.2, ex. Ca, ex. Mg in mequ/100g soil and Base Saturation (%).

Conclusions

The studied Arenosols were formed on soft, unconsolidated Neogene and Quaternary sands sediments with a sandy texture and composition on flat, sloping, mountainous relief. The weathered soil-forming rocks have a direct influence on the processes of soil formation and properties. Arenosols have a primitive structure of the soil profile and its horizons: A(AC) – AC – C. The depth of the profile (A+C) is often about 30-120 cm. They have average texture class of loamy sandy or sandy with above 80 % of sand in the soil profiles which is main diagnostic criteria for Arenosols classification.

The content of organic carbon has very wide content form 0.18 up to 9 % but averagely it is 1.87. The high content is due to mixture of forest litter in the soil surface. The content of the total nitrogen show similarity with organic carbon and the soils are with poor reserves about 0.08%.

The reaction of the soils is acidic with low sorption capacity and they are weakly colloidal. The exchangeable acidity and exchangeable aluminum were established. Calcium and magnesium are insufficient, which determines higher intensity of the weathering and acidifications of the studied soils. Soil horizons have values for saturated and unsaturated soil with basic cations. Profiles 3 and 4 are Eutric Arenosols because all soil horizons have 50% or more base saturation. Other soil profiles are Dystrict Arenosols.

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