Bulletin of the *Transilvania* University of Braşov
Series II: Forestry • Wood Industry • Agricultural Food Engineering • Vol. 14(63) No. 2 – 2021
https://doi.org/10.31926/but.fwiafe.2021.14.63.2.1

INFLUENCE OF SOIL GENESIS FACTORS ON GURGHIU MOUNTAIN FOREST SOILS' PHYSICAL AND CHEMICAL PROPERTIES

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Abstract: *This research aimed to determine the values of chemical properties and the relationships between the main pedoecological factors that characterize the soils in the Gurghiu Mountains. The mapping surveys were carried out on an area of 4,647.36 ha located in the mixed mountain forest sites (FM2) (1,000–1,400 m altitude). The area was stratified into homogeneous site units in terms of climate, hydricity, and trophicity. At the level of the elementary site units, 35 main soil profiles and 46 control profiles were placed. The number of profiles was determined statistically to ensure an error of no more than 10%. Soil samples collected from the main profiles were analyzed in the laboratory. Soil's properties values decreased on the soil's profile (humus content from 15 to 2%, nitrogen from 1.1 to 0.5%, sum of exchangeable hydrogen from 20 to 9 me/100 g soil, and total cationic exchange capacity from 38 to 20 me/100 g soil), except the pH and the base saturation degree (the pH increased on profile from 4.5 to 6, and the base saturation degree from 40 to 70%). The soil properties, except for moisture, were significantly affected by altitude, and decreased when the altitude increased. Soil trophicity can be characterized by a soil index, the values of which were between 17 and 42 for the analyzed soils. These values indicated soil-specific trophicity levels from oligotrophic to eutrophic.*

Key words: *forest soil, humus, nitrogen, soil reaction, potential soil trophicity.*

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1. Introduction

Forest site determines the growth and development of stands through its component elements - a specific location in the geographical space, topography, lithological substrate of the soil, soil thickness and morphology on the profile. The influence of topography is shaped by the main geomorphological factors: altitude, exposure, and slope. These factors are conditioning soil properties, natural spread of species, and stand productivity.

Soil is a major element of forest sites and provides an ecological environment for biocenosis through its characteristics and relations with environmental factors. By its the edaphic volume, soil ensures the rooting space, as well as the supply of water and nutrients which are required for the development of physiological and bioecological processes. Regarding climatic conditions, a vegetation period is recognized in temperate zones, which constitutes the time factor of the forest site, while the edaphic volume represents the space factor [7], [23], [25].

Climatic and edaphic factors have different values and, consequently, indirectly influence the life and growth of plants. Multiple relations and interactions are established between them; hence, the compensating or summing effects of these factors is often possible, each one of which is indispensable to plants and cannot be replaced by any of them [7], [26].

Among the characteristics of soils, humus is the main element that contributes to its fertility. Humus is also a good indicator of present and past climates [4], [18] because it is the result of complex interactions between the composition of trees, soil properties, environmental conditions, and microbial activity [4]. Humus type is used to assess site quality and is an important indicator of tree growth, regeneration conditions, and vegetation types [20], [23], and it can help following the effects of tree development [11]. The types of humus (mull, moder, and raw humus) vary depending on climate, parent material [19], [21], the nature and composition of forests [1], and management type [5], [9]. The chemical composition of humus is the result of several factors, such as the type of vegetation, climatic conditions, and soil microbial communities [3], [20, [22]. The impact of tree species on soil fertility also varies depending on parent material, climate, and management style applied [2].

As a geomorphological element, altitude is a driving factor for the distribution of soils and it influences their characteristics and humus formation [4], [17], [23], [26]. Altitude also influences the accumulation rate of carbon into soil, which depends on the nitrogen accumulation rate [22]. In turn, the accumulation of nitrogen into soil is influenced by climatic conditions but also by the soil's physical and chemical properties [22]. Nitrogen content in the soil decreases with altitude and is closely related with site quality and plant growth [15], [30]. Furthermore, soil pH is negatively related with altitude [6], [10], [24]. Thus, a high pH level corresponding to low altitudes can be correlated with the increase of microbial biomass and bacterial diversity [3]. The rate of mineralization of organic matter and nitrification are dependent on tree species [2], [12].

Volcanic rocks are favorable for the formation of andosols and andic subtypes of other types of soils which exhibit horizons with andic properties (the presence of allophanes, high organic matter content, dark soil color, high total cationic exchange capacity, etc.) [26]. Andosols are soils formed on volcanic rocks [13]. In Romania, andosols can be found particularly in the volcanic mountains Călimani–Gurghiu–Harghita [14]; the specific characteristics of andosols are allophanes, Fe/Al humus complexes, but also a high total cationic exchange capacity. Allophanes have been identified at altitudes between 700 (900)–1,800 m in the Harghita Mountains [16]. Despite having a high coarse content, andosols are deep soils and, therefore, achieve medium to large edaphic volumes and high trophicity. The chemical properties of andosols vary substantially on the profile but also in relation to geomorphological factors.

This research aimed to determine the variation of chemical properties and to characterize the relations between the main pedoecological factors (soil genesis) that characterize the soils in the Gurghiu Mountains.

2. Materials and Methods

2.1. Study Area

This research was carried out in the Gurghiu Mountains, from the Eastern Carpathians of Romania, in production unit IV Fâncel (46° 47′59″ N; 25° 9′22″ E) from Fâncel Forest District. The forests are located at altitudes between 700-1,500 m, on andesite-type volcanic rocks. A wide variety of geomorphological factors are found in the stands. The inclination of the terrain is frequently between 25 and 35 degrees, and the most common aspects are the sunny and partially sunny ones. The climate is characterized by an average annual temperature of approximately 5°C and average precipitation of about 1,000 mm.

2.2. Field Data

For the development of field work, the physical–geographical conditions in the area were documented based on geological, geomorphological, and pedological maps from the literature. Information regarding forest management planning (description of the stands and thematic maps) was used, and the area of the forest district was stratified in relation to the main geomorphological factors (altitude, aspect, and slope) and stand structure. The mapping work was carried out on an area of 4,647.36 ha. Site quality was determined directly based on research of the edaphic elements of the sites [7], [23], [26] within the production unit. Depending on the soil genesis factors and the physical and chemical properties of the soils in the study area, eutric Cambisols and andic dystric Cambisols were identified. In some cases, forest site quality was determined indirectly according to some dendrometric characteristics of the stands (average height and dominant height) [8], the type of humus, and plant cover type. The sites in which the analyzed soils were identified are part of the mixed beech–coniferous forest types (FM_2). In carrying out the research, the division of the forest in compartments (subcompartments) was taken into account. All existing compartments were reviewed and verified with the aim of maintaining the same site conditions [27, 28]. These development units were grouped in homogeneous units in terms of climate, trophicity, and water. These factors were assimilated with the elementary sites specfic units at the level of which 35 main soil profiles and 46 control profiles were placed, according to the recommendations of the technical guidelines for forest management. The number of profiles was determined statistically, depending on the coefficient of variation of soil properties, which has an average value of 30, to ensure an error of no more than 10%. For each profile, the coordinates were determined so that the soils could be stratified in relation to the main geomorphological factors (altitude, aspect, and terrain inclination). Soil samples were collected from each diagnostic horizon and were analyzed in the Laboratories of Pedology and Forest Sites at the Brasov Office of the I.N.C.D.S. "Marin Drăcea" and at the Faculty of Silviculture and Forest Engineering of Brașov. The separation of the horizons in the profile was done according to color, structure, and texture. The collection of soil samples from each horizon was performed, initially from the lowest horizon of the profile and continuing upwards on the profile. Samples were collected from the middle of the diagnostic horizon, except for horizon A. In this case, the samples were collected from the entire horizon, as well as for horizons smaller than 10 cm. Soil types were established based on the data collected in the field and the results of the laboratory analysis. The preparation of the soil samples was based on the ISO 11464 method [31]. The samples were either air- or oven-dried at a temperature of 40 °C and stored until they could be chemically analyzed. The laboratory analysis determined the following properties: pH (in H_2O), percentage of humus (H), total nitrogen (N), sum of exchangeable bases (SB), sum of exchangeable hydrogens (SH), total capacity of cationic exchange (T = SB + SH), base saturation degree (V), and humidity (U). pH was electrochemically determined in water using a Thermo Orion 3 pH meter. The soil humus content was determined using the humid oxidation method and titrimetrical dosage—the WALKley Black method. The total nitrogen in the soil was calculated using the humid mineralization method and titrimetrical dosage—the Kjeldahl method—with a Gerhardt mineralizer and still [25]. The relation between these properties and the geomorphological factors was studied through the ANOVA test. The potential trophicity was estimated at the level of each horizon [7], [23], according to the relation (1):

$$T_P = H \cdot d \cdot V \cdot 0{,}1 \cdot r_V \qquad (1)$$

where:

H is the percentage of humus in the horizon [%];

d - the thickness of the horizon [dm];

V - the base saturation degree (V) at pH = 8.3;

r_v i the ratio between the volume of fine soil (without coarse fragments, roots, etc.) and the total volume of the soil.

The statistical analysis which considered the elements of potential trophicity (H and V) indicated a significant correlation between their values. By multiple regression, the relation between the soil H, N, pH, SB, and SH was analyzed at a confidence threshold of 95% (p-value <0.05). These properties were also used in a mathematical relation to estimate the edaphic index (I_e) that can characterize the level of soil trophicity in the area, according to relation (2). Its values were correlated with potential trophicity (T_p) and altitude.

$$I_e = \sqrt[3]{H \cdot N \cdot pH \cdot SB \cdot SH} \qquad (2)$$

3. Results and Discussion

In the composition of the forest, fir and spruce represented 60% and beech and other deciduous trees, 40%. In relation to geomorphological factors, 56% from the management unit area was located at altitudes between 1,000-1,400 m, 42% on partly sunny and partly shaded slopes, 39% on sunny slopes, and 69% had an inclination between 26 and 35 degrees (Figure 1).

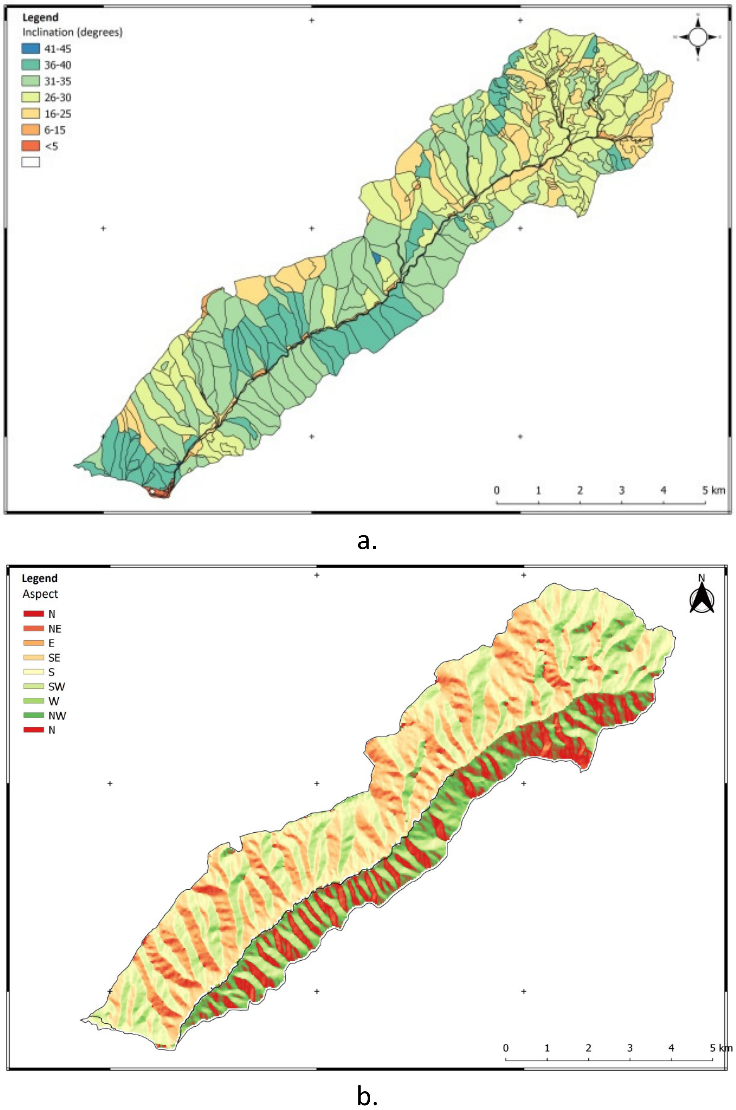
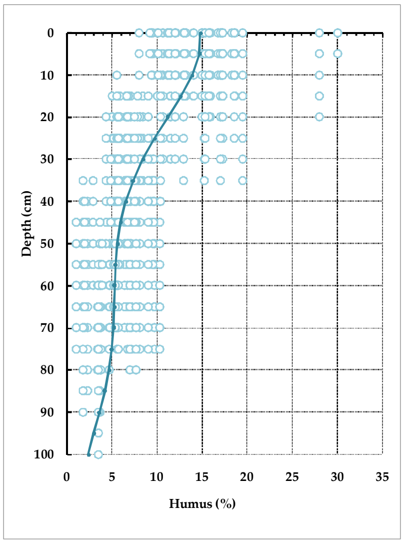


Fig. 1. *Distribution of management unit area in relation to inclination (a) and aspect (b)*

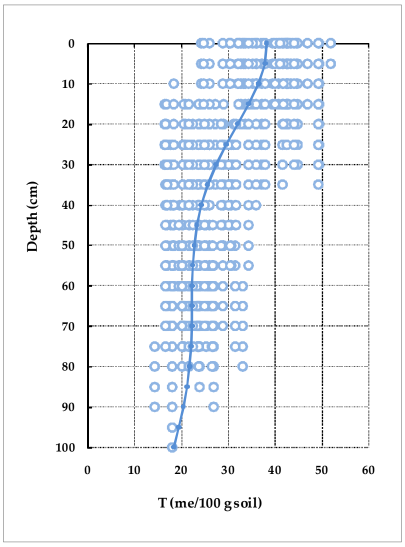
The humus (H) in the study area was of mull and mull–moder andic type and had values of over 20%. The humus decreased on the profile, from average values of 15% in horizon A to average values of approximately 2% in horizon B (Figure 2a).

Nitrogen (N) in horizon A was between 0.40 and 1.1% and also decreased on the profile, the lowest values being recorded in horizon B. The same was followed by other properties, such as the sum of exchangeable bases (SB), the sum of exchangeable hydrogens (SH), and the total cationic exchange capacity (T). T values decreased on the profile, from 38 in horizon A (first 10 cm) to 20 me/100 g soil in B (90 cm in depth) (Figure 2b). The sum of exchangeable bases (SB) was between 30-50 at the level of horizon A and 51-75 me/100 g soil at the level of horizon B. The base saturation degree (V) increased on the profile (Figure 2c). Average SH decreased on the profile from 20 in horizon A (first 10 cm) to 9 me/100 g soil in horizon B (90 cm in depth) (Figure 2d). For eutric Cambisols from the Eastern Carpathians, SH values reached 14.834 me/100 g soil [24].

The humidity remained somewhat constant in the soil profile. This finding explains the soils' favorability for the stands in the area and the high productivity of these stands. The average values of nitrogen (N) decreased on the profile from 0.63 in horizon A (first 10 cm) to 0.18% in horizon B (at 90 cm depth) (Figure 2e). In contrast, the soils were high to very high acidic (pH 4.0–5.0) in horizon A and low to moderate acidic (pH 5.1–6.2) in horizon B (Figure 2f). In the B horizon of the cambisols from the mixed mountain stands from the Eastern Carpathians, the average pH values of 4.88 and V values of 70.78% were found [24]. The reduction in pH was also observed in relation to altitude [6], [10], [29].



a.



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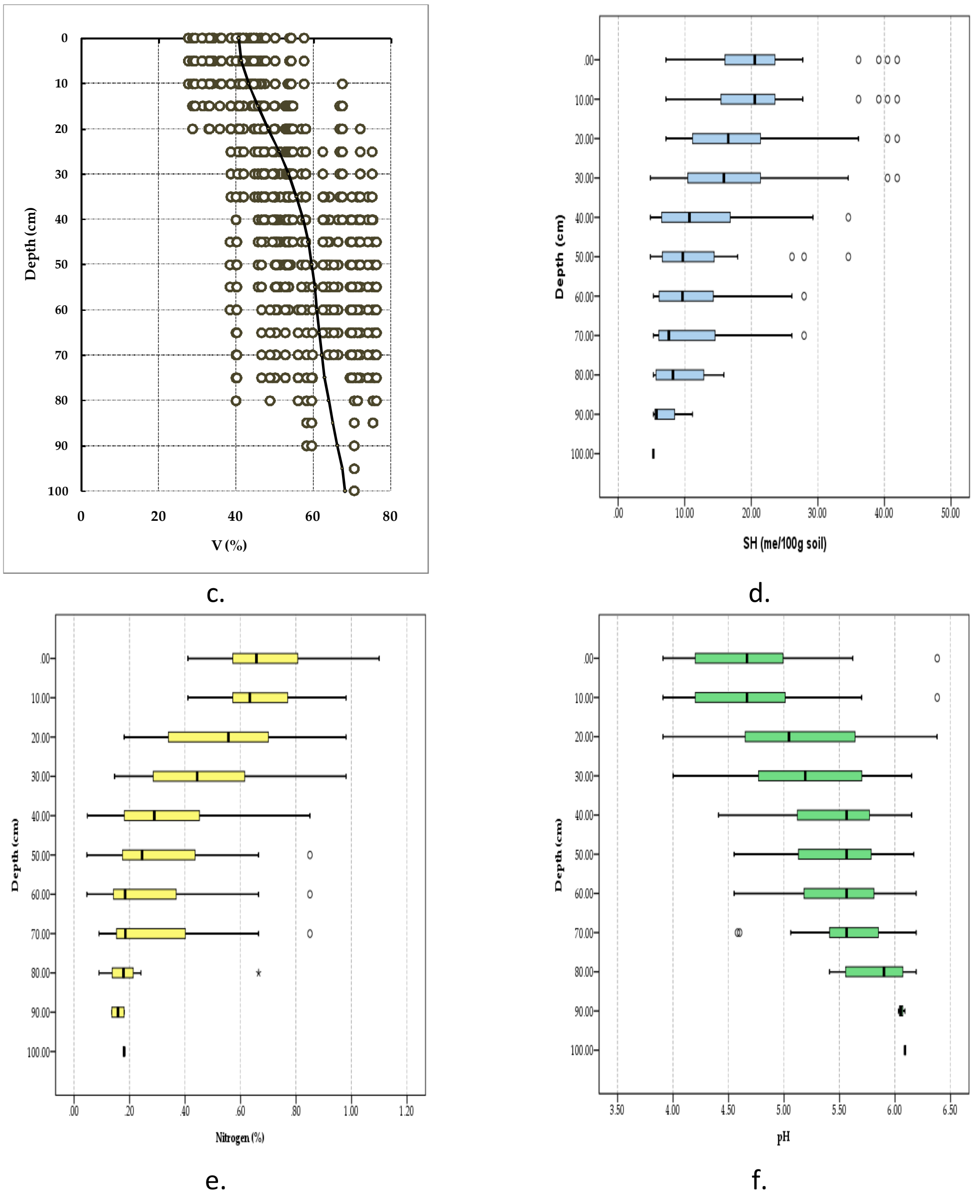
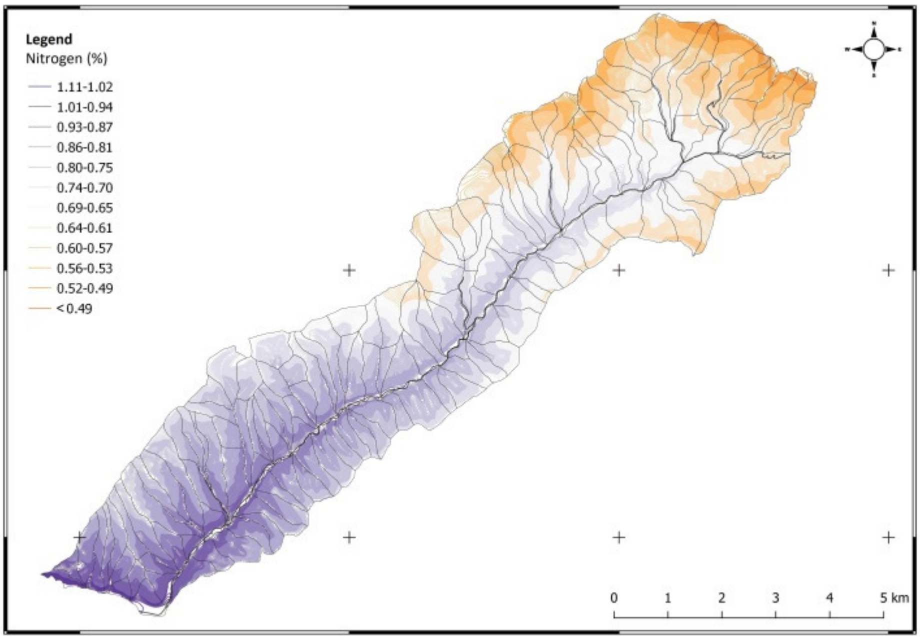
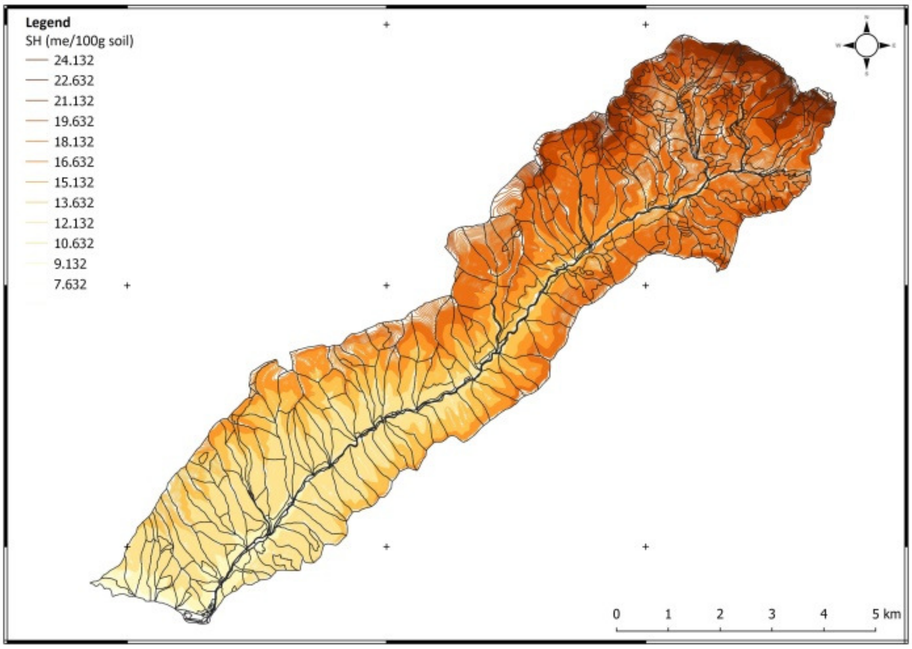


Fig. 2. *Variation of soil properties on the profile: humus content (a), total cationic exchange capacity (b), base saturation degree (c), sum of exchangeable hydrogens (d), nitrogen content (e), and pH (f)*

The values of the determined properties (i.e., H, N, pH, SB, and V) showed the same decreasing trend as the altitude had increasingly higher values, while SH increased with altitude. Figure 3 shows the variation in N and SH.



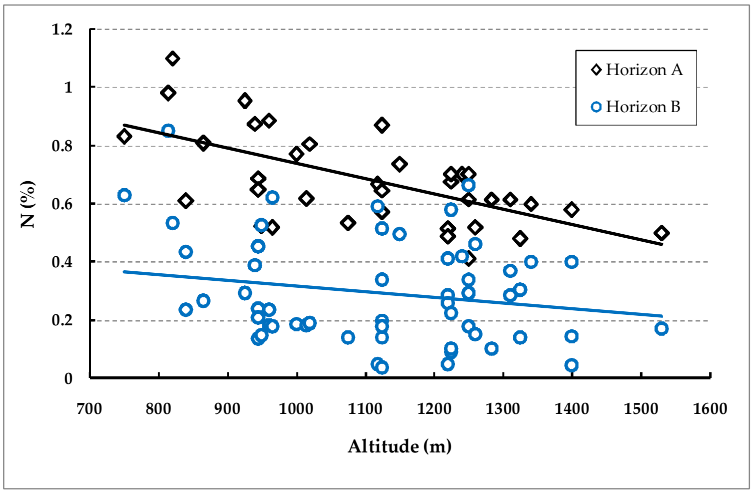
a. N



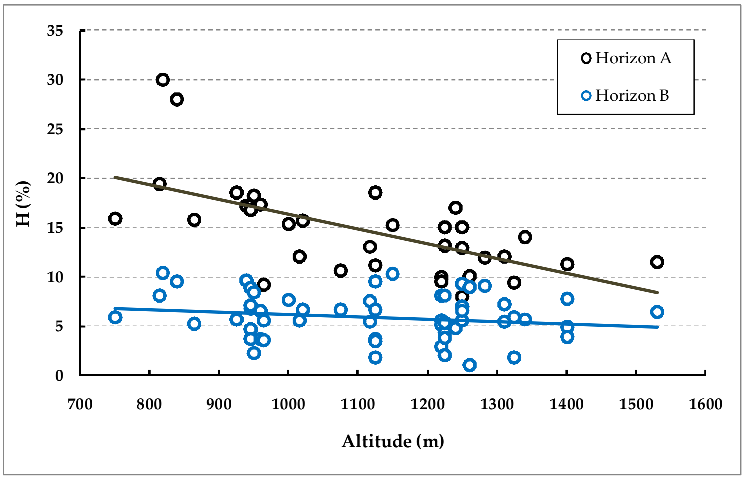
b. SH

Fig. 3. *Variation of the soil's physico–chemical properties (N and SH) within the management unit*

The nitrogen richness was closely correlated with the percentage of humus (p-value < 0.001) and depended on the amount of organic matter contained in the soil. This dependence explains the reduction of nitrogen on the profile and in relation to the increase in altitude (Figure 4a), this trend being more evident in horizon A. Furthermore, the humus content decreased as the altitude increased (Figure 4b). In contrast, the proportion of hydrogen cations (SH) increased as the leaching and debasification processes became more intense due to the increase in altitude (Figure 3b). On the profile, the acidification of the soils presented maximum values in horizon A, the coniferous stands having an active role due to their proportion of participation that increased with altitude.



a.



b.

Fig. 4. *Variation of total nitrogen (a) and humus content (b) in relation to altitude*

The values of the analyzed soils' chemical properties showed different levels of significance in relation to the main geomorphological factors (altitude, aspect, and inclination) (Table 1).

Table 1

Significance of correlation between geomorphological factors and soil characteristics

Variables	Altitude	Aspect	Inclination
	Pearson Correlation		
H (%)	-.291**	-.079	.056
N (%)	-.277**	.013	.020
pH	-.545**	.187**	.399**
SB (me/100 g sol)	-.576**	.108	.189**
SH (me/100 g sol)	.321**	-.102	-.151**
T (me/100 g sol)	-.446**	.037	.186**
V (%)	-.150**	.070	.036

** Correlation significant at 0.01 level

The nutrients accessible to plants varied according to the type of humus, humus content, and soil absorption properties. Their values differed on the soil profile and were specific to each horizon. For the analyzed soils, the H and V values differentiated on horizons led, according to relation (1), to values of potential trophicity (T_p) between 12 and 238. On the profile, the T_p values decreased as the content of humus decreased, and the T_p values were increasingly lower as the altitude increased.

I_e varied in relation to altitude, from 42 ÷ 700 meters to 17 ÷ 1,550 meters. In relation to the edaphic index (I_e) values associated with the potential trophicity values (T_p), the soils in the analyzed study area could be classified as follows:

- I_e = 13 … 17 (oligo-mezotrophic);
- I_e = 17.1 … 26 (mezotrophic);
- I_e = 26.1 … 42 (eutrophic);
- I_e > 42 (megatrophic).

In the management unit, I_e frequently presented values between 26 and 42, which are characteristic to the eutrophic soils (Figure 5). Values lower than 17 characterize the soils on which Norway spruce stands are located at altitudes higher than 1,500 m.

I_e indicated a high level of trophicity up to 1,350 m, after which it decreased, reaching an oligotrophic level at an altitude of 1,550 m.

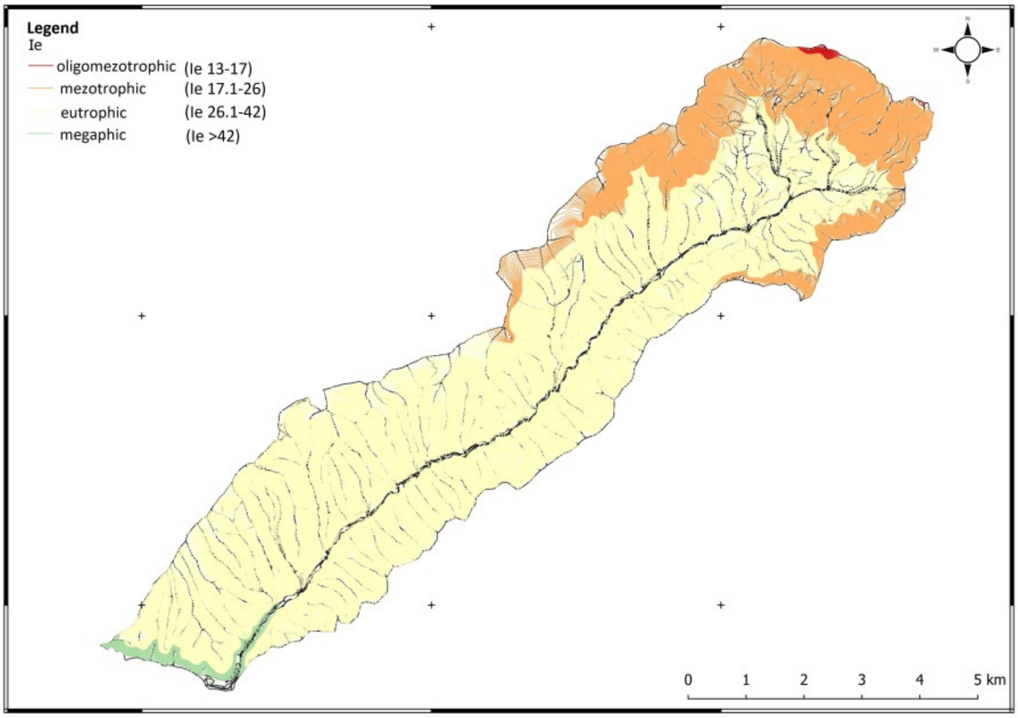


Fig. 5. *Variation of edaphic index (I_e) of the soils in the management unit*

4. Conclusions

The chemical properties of the soils are influenced by the soil genesis factors such as the rock type, topography, climatic conditions, and forest vegetation. The rock type significantly influences the texture, bulk density, and soil reaction. The type of vegetation and climate determine the formation of humus type, but they also influence other chemical properties of the soil (SB, SH, T, V, nutrient content). The values of the analyzed properties were found to be highly different in the two horizons, A and B. For H, N, SB, SH, and T, the values decreased on the soil profile, compared to those of pH and base saturation degree. Altitude is the main geomorphological factor that determines the vertical stratification of climatic conditions and soils, the spread of species, and forest biocenoses. Except for humidity, all analyzed properties were influenced by altitude. Humidity values were statistically significant (p-value <0.01) only in relation to aspect and slope. The significant correlation between the H and V values justifies their use in relation to the potential trophicity index (T_p). The relationship between soil property values was expressed by an edaphic index (I_e), which characterizes mixed stand soils as mesotrophic and eutrophic.

Acknowledgements

We thank the staff of the Laboratories of Pedology and Forest Sites of the I.N.C.D.S. "Marin Drăcea" Brașov Office and the Faculty of Silviculture and Forest Engineering of Brașov for the chemical analysis of the soil samples.

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