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Study of basic indicative parameters for soil health in beech forests of Petrohan area, Western Bulgaria

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Abstract. Soils in forest areas are one of the most vulnerable terrestrial ecosystems, which are subject to sensitive changes because of anthropogenic impact and global climate changes. Studying the main soil indicators on which soil health depends is essential to setting realistic goals for its maintenance and/or improvement. The study focuses on assessment of basic indicative soil parameters, which are directly related to the health status of the soil. A total of 10 soil profiles of *Dystric* Cambisols from Western Bulgaria were studied. The soil profiles were assessed as shallow. The average depth of *A* horizon was 11 cm. Very low pH values were established in *A* (3.7 to 5.3) and *Bw* horizons (3.8 to 4.7) of the soils which indicate ongoing acidification processes in soil depth. The studied soils were assessed as porous with ideal bulk density values. They were moderately (144 t/ha) to very well stocked (665 t/ha) with humus and total nitrogen, but poor on available potassium and phosphorous. All the soils were assessed as unsaturated with bases. Their base saturation (BS) values ranging between 5% and 34%. The obtained results showed that low soil depth, acidic soil reaction, low BS, and cation exchange capacity (CEC) are the main prerequisites for the deterioration of soil health. The studied soils are sensitive to acidification processes, which can lead to poor soil health status and, therefore, to soil degradation. It is highly recommended to continue the monitoring on the health status of these soils, because forest soils are becoming more and more susceptible to degradation processes.

Key words: forest soils, soil acidity, soil organic C, Cambisols.

Introduction

Soil is a dynamic living system whose health is fundamental to its productivity and ecological functions globally (Doran et al., 1996). The main functions of soil are related to ensuring the growth of plants, regulating the movement and purification of water, transforming organic matter and transporting nutrients (Lal, 2016). It provides a habitat for microorganisms and animals and buffers environmental changes by carrying out several processes, such as water retention, chemical oxidation and microbial decomposition (Weil & Brady, 2017). The effectiveness of soil to carry out its inherent physical, chemical and biological processes under specific geographical and climatic conditions determines its ability to provide these ecological services and this gives rise to the term „soil health". Soil health is described as the continued ability of the soil to function as a vital living system, analogous to the health of an organism, person or community (Larson & Pierce, 1991; Doran & Parkin, 1994). These functions can maintain soil biological productivity, maintain environmental, air and water quality and ensure plant, animal and human health (Warkentin, 1995; Doran & Zeiss, 2000; Moebius-Clune et al., 2016; Sigua, 2018). Soil health refers to the ability of soil to provide ecosystem services and to indicate how well it can perform its ecological functions (ITPS, 2020). Soil is considered „healthy" if it offers equivalent or better ecosystem services compared to undisturbed soils of the same soil type that are not subject to anthropogenic pressures. If it does not offer these services, the soil is considered „unhealthy" and cannot perform the typical ecological functions of such soils (Lehmann et al., 2020; Baritz et al., 2022).

The various physical, chemical and biological aspects of soil are collectively referred to as „soil health". Deterioration of soil health is defined as „the loss of its inherent physical, chemical and biological properties, caused by natural or anthropogenic processes, resulting in a negative effect on the soil ecosystem" (Nunes et al., 2020).

For soils used in agriculture, numerous classification indices have been developed to assess the quality of the soil and its health. The main indicators of soil characteristics of healthy soil from agricultural lands are as follows: proper tillage, sufficient depth of roots to access water and nutrients, adequate fertilization (but not in excess) with nutrients, optimal pH, low levels of pathogens and insect pests, a high and diverse population of beneficial microorganisms to decompose organic matter and ensure nutrient cycling and maintain structure of the soil, low weed pressure, free of harmful chemicals and toxins, and soils resistant to degradation (Phatak & Diaz-Perez, 1998; Magdoff, 2001; Mann et al., 2019).

In general, the assessment of the health status of agricultural soils includes key physical, chemical and biological indicators, selected for their relevance, sensitivity, consistency and cost (Schindelbeck et al., 2008; Idowu et al., 2008). Most often, when assessing the health of soils from agricultural lands, the soil parameters used vary between 9 and 16 indicators. The following parameters are tested as standard: soil texture, active moisture capacity, soil compaction, water resistance of structural aggregates, organic matter content, soil protein extractable by autoclave citrate extraction, soil respiration, active carbon and nutrient stock substances. Indicators are scored individually out of 100 and averages are used to generate an overall soil health score.

There is still lack of scientific information regarding the selection of basic indicative soil parameters for the assessment of the health status of forest soils (DeLuca et al., 2019). Tree species, climate, bedrock, and topography significantly influence soil formation in temperate forest areas (Binkley & Fisher, 2012). The main tree species in forest communities directly affect soil chemical parameters (e.g. pH), biological component (litter decomposition rate and root system depth) and the amount of available soil moisture (Adams et al., 2019). However, there is no comprehensive and updated body of knowledge for identifying healthy soils (Baritz et al., 2022). Furthermore, there are still no clearly defined soil parameters to be used for a unified system for comprehensive soil health assessment of soils in the forest areas. Only some authors (Ngaiwi et al., 2019; Page-Dumroese et al., 2021) in recent years have paid more attention to the ecological functions of soils in forest areas, due to climate changes and the fight against global warming of the planet, as well as the importance of these soils to the productivity of forest stands as a source of wood and oxygen, and the range of ecosystem services they provide.

The main aim of the present study was to assess the basic indicative soil parameters which were directly related to the health status of soils in the forest areas of Petrohan, Western Bulgaria.

Materials and methods

Study area

The study was conducted on the territory of Petrohan Training and Experimental Forest Range (TEFR Petrohan). It is located on the northern slope of Balkan Range Mountains, Western Bulgaria. Within this study area, 10 soil profiles were set, covering an elevation gradient of 757 -1497 m a.s.l. (Table 1).

The focus of the study were soils, classified as *Dystric* Cambisols (WRBSR, 2006, 2007). These soil units were developed mostly on acidic igneous and metamorphic rocks. The soil forming rocks are mainly granites, which are rich in free quartz and that is a prerequisite for acidic reaction of the soils (Haldar, 2020), granodiorites, diorites, and gneisses. There are also finite areas with sedimentary rocks, mainly limestone. The relief of the studied area is typically mountainous. It is characterized by steep slopes, deep river valleys, and steep secondary ridges (Ninov 2002).

The climate is moderate continental and typical mountainous. According to Koleva-Lizama (2006), the absolute air temperature minimum is -28.0°C. Temperatures vary between 19.6°C and 20.2°C in the summer, but they can reach up to 26.0–27.0°C. The amount of annual precipitation is 1060 mm (Koleva & Peneva, 1990). The Petrohan pass area is considered to be the region with the highest average annual precipitation in Bulgaria.

Among the deciduous species, common beech (*Fagus sylvatica* L.) is the most widespread tree species in the studied area (Petrova et al., 2019). It has significantly impacted the organic matter that enters the soil surface and largely determines the composition of the humus and therefore the uptake of nutrients in the soil. Peters (1997) reported that common beech aboveground litter fall have acidifying effect on the soil.

Cambisols are the most widespread soil order on the world's soil map distribution (Jordanova, 2017). They are the most common soils on the territory of TEFR Petrohan, occupying 87.9% of the forest range's total area. According to WRBSR (2006–2007) requirements they were identified as *Dystric* and *Eutric* Cambisols (Malinova & Petrova, 2019). Several authors focused their research on soil genesis and soil fertility of these soil units in the area (Donov, 1976; Donov & Yordanov, 1988; Petrova, 2018; Malinova & Petrova, 2019).

Soil sampling and analyses

Ten representative areas were chosen for setting the soil profiles on the territory of TEFR Petrohan (Table 1). To have comparability of the results regarding the indicative parameters for soil health assessment, were selected areas with soils formed on acidic igneous rocks and developping under the influence of pure beech stands. Litter samples were taken by layers *L*, *F*, and *H*. Where layers could not be differentiated, the litter sample was taken as one pooled sample (*LFH*). Soil samples for chemical analyses were taken from each mineral horizon of the studied soil profiles. Steel cylinders were used to determine bulk density for each mineral horizon of the soil. All soil analyses were carried out in the Central laboratory at the University of Forestry.

To assess soil health status of the studied soils 16 indicators were selected and analyzed for each mineral horizon of the profiles – soil depth, pH (H_2O), pH ($CaCl_2$), exchangeable acidity, bulk density, particle density, soil porosity, soil texture, organic C, total N, org. C/N ratio, available P_2O_5, available K_2O, water holding capacity (available soil water content), cation exchange capacity (CEC) and base saturation (BS).

Table 1. Geographical coordinates of soil profiles on the territory of TEFR Petrohan.

Soil profile (SP)	Coordinates	Altitude, (m a.s.l.)	Exposition	Soil unit
1	43° 09' 13.06" N 23°08' 55.78" E	757	E	*Dystric* Cambisols
2	43° 11' 03.47" N 23°07'10.58"E	925	SE	*Dystric* Cambisols
3	43° 10' 51.29" N 23°07' 07.40" E	942	E	*Dystric* Cambisols
4	43° 08' 06.74" N 23° 08' 36.92" E	1043	S	*Dystric* Cambisols
5	43° 07' 48.30" N 23° 08' 31.42" E	1187	NW	*Dystric* Cambisols
6	43° 07' 27.50" N 23° 07'30.26" E	1420	NE	*Dystric* Cambisols
7	43° 07' 41.34" N 23° 07' 39.79" E	1442	E	*Dystric* Cambisols
8	43° 07'11.64" N 23° 06' 48.97" E	1448	SW	*Dystric* Cambisols
9	43° 07' 59.60" N 23° 06' 34.12" E	1450	SW	*Dystric* Cambisols
10	43° 07' 21.20" N 23° 07' 12.91" E	1497	E	*Dystric* Cambisols

To define a forest soil as healthy one, it must have the following characteristics: to ensure sufficient soil depth for tree rooting system, to have slightly acidic to neutral soil reaction, to be well stocked with humus, to have enough nitrogen content, available P_2O_5, available K_2O, to ensure enough available water content for optimal tree growth, and to perform all of its ecological functions and ecosystem services.

The following methods were used to determined basic soil parameters: soil pH (H_2O) and pH ($CaCl_2$) - ISO 10390; Exchangeable acidity – ISO 14254 (with $BaCl_2$); Bulk density - measured according to ISO 11272; particle density - pyknometer method (ISO 787-10:1993).

Soil porosity (%) was calculated using the following formula according to Skidmore (1983):

$$Soil\ porosity = \left(1 - \frac{Bulk\ density}{Particle\ density}\right) \times 100.$$

Soil texture was determined according to ISO 11277. The content of humus and soil organic carbon was determined by the modified Turin's method – 120°C, 45 min and $CuSO_4$ as a catalyst (Kononova, 1963; Filcheva & Tsadilas, 2002). Total nitrogen was determined by the Kjeldahl method (1883) using a Kjeltec Auto 1030 Analyzer. The acetate-lactate method was used to determine the content of P_2O_5 and K_2O (Ivanov, 1984). ISO 11260 (2018) was applied for the analyses of the exchangeable cations (Ca^{2+}, Mg^{2+}, K^+, Na^+). Available water content was measured according to the Kachinskii method (Kachinskii, 1963), while bulk density analysis followed ISO 11272. Additionally, the skeletal coefficient was determined using the Kachinskii method (Kachinskii, 1963).

Results and Discussion

Forest soils differ significantly from agricultural soils (Paltineanu et al., 2020) because of the complexity of the interrelationships in forest ecosystems, that's why soil health is a multicomponent concept in forest territories. It is much more complex to assess compared to herbaceous species that are used in agriculture for food sources. This is due to much more competitive relationships between different tree individuals in forest ecosystems regarding the use of soils to obtain nutrients and water (Trogisch et al., 2021). A major distinguishing feature of woody forest vegetation is that, unlike agricultural crops, it is long-lived. That is, they need much larger and different amounts of nutrients and available soil moisture to ensure optimal tree growth during the individual phases of development of woody organisms (coniferous or broad-leaved), which last tens or hundreds of years in comparison to herbaceous plants.

In order to assess soil health in its entirety in relation to forest ecosystems, very long periods of monitoring and assessments of a complex of soil parameters and indicators, as well as a multicomponent database, are required. In the present study, basic soil parameters were investigated, which were evaluated in order to establish the soil health of specific soil units. A total of 10 soil profiles (SP) were set in mature natural seed stands of common beech (*Fagus sylvatica* L.) in Western Balkan Mountain range.

Data on the active reaction of soil solution (Fig. 1) is a key indicator of soil health as it plays a major role in nutrient plant uptake (Sousa et al., 2007). In *A* horizon of the studied Cambisols soil units, the soil reaction was assessed as extremely acidic (SP1 and SP8) to moderately acidic (SP4). The obtained low pH values were prerequisite for destructive processes in the soil and deterioration of soil health. It should be noted that the average soil depth of *A* horizon was 11 cm. Low depth of humus accumulative horizon indicates that litter fall and organic matter have a significant impact on soil reaction values. The lower values of the litter fall reaction contributed to soil solution acidification in the *A* horizon. In soil depth the pH (H_2O) remained in acidic spectrum. It was assessed as extremely acidic (SP8) to very strongly acidic (SP4). The results obtained for *Bw* horizon showed that their values were very close to these in *A* horizon. This indicated that processes of acidification of the soil took place in depth of the soil profiles.

Low pH values of Cambisols in the Petrohan area have been reported in previous studies (Malinova & Petrova, 2019; Petrova et al., 2019). Extremely low pH values pose a great risk to soil health and can lead to the initial phase of the podzolization process (Petrova, 2018).

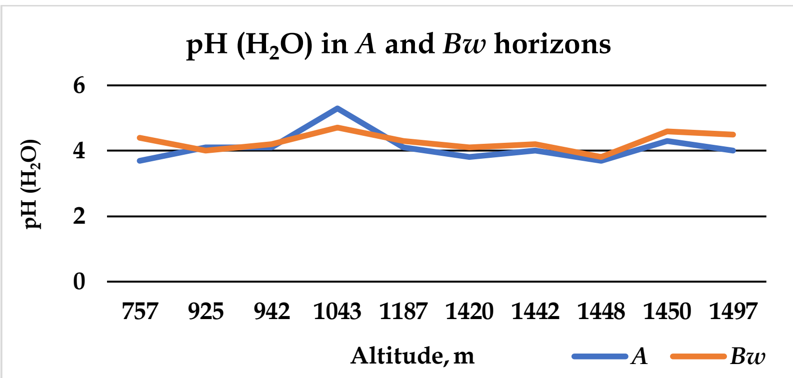

Fig. 1. Soil reaction (pH H_2O) in *A* and *Bw* horizons of the studied soil profiles.

Exchangeable acidity is also a very important indicator for soil health. Its values were measured potentiometrically (pH $CaCl_2$) and titrimetrically (with $BaCl_2$). The pH ($CaCl_2$) values were used to estimate the buffering capacity of the soil according to Ulrich's scale (1983). The obtained results showed that the buffering capacity of the soil in *A* horizon in 70% of the cases is realized by a predominant process of the consumption of the protons due to the expense of the dissolution of the iron oxides (SP1, SP2, SP5, SP6, SP7, SP8 and SP10). In 20% it was due to the weathering of secondary silicates (clay minerals) and release of exchangeable aluminum. The soil has high buffering capacity (SP3 and SP9). Only in 10% it was due to the exchange of protons with basic cations – Ca^{2+} and Mg^{2+}, which are adsorbed on the surface of the colloidal structures (SP4), and in this pH range, the buffer capacity of soils is low. As for the *Bw* horizon, the predominant process was weathering of secondary silicates and the buffering capacity is assessed as high (SP1, SP2, SP3, SP5, SP6, SP7, SP9, and SP10). In SP4 soil buffering capacity was realized due to exchange of protons with basic cations, and in SP8 – due to the dissolution of the iron oxides (Fig. 2).

The values obtained for titrimetrically measured exchangeable acidity (EA) are shown on Fig. 3. For the studied Cambisols, it was established that the EA varied in a wide range in *A* horizon - it was assessed as low (SP4) to very high (SP1). The average value of EA was 6.75 cmol(+).kg^{-1}, which is higher than the most Cambisols developed under the influence of beech forest in the area (Malinova & Petrova, 2019). In *Bw* horizon EA values were assessed as low (SP4) to average (SP6). High exchange acidity values indicate ongoing destructive processes in the humus-accumulative horizons of the studied profiles, which negatively affect their soil health status.

On one hand, the high EA affect negatively soil health status, but on the other hand, according to Thai et al. (2023), common beech forest can reduce and mitigate the high soil acidification. Regardless of the extremely low pH values, the common beech stands successfully cope with soil acidification and this does not negatively affect their growth.

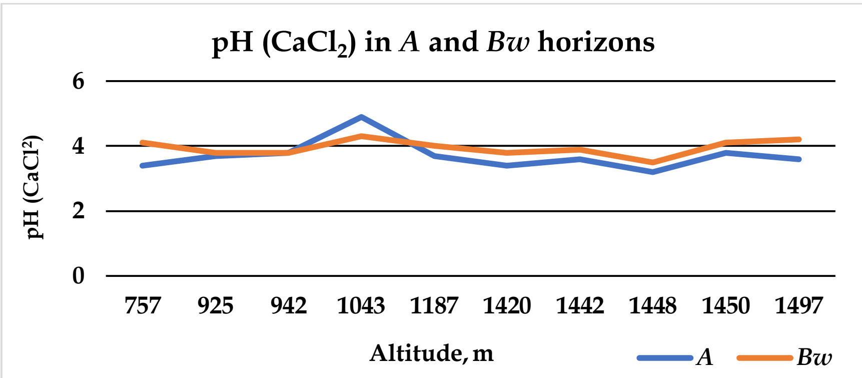

Fig. 2. Soil reaction (pH $CaCl_2$) in *A* and *Bw* horizons of the studied soil profiles.

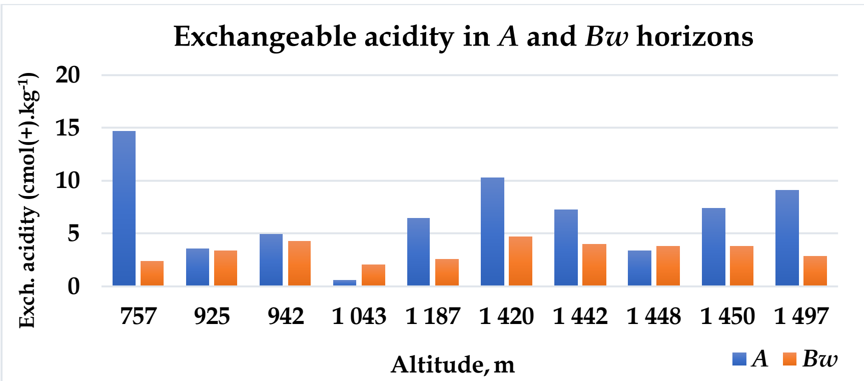

Fig. 3. Exchangeable acidity in *A* and *Bw* horizons of the studied soil profiles.

Soil texture is an important factor, which can directly affect the health status of the soils. It has been considered a very stable indicator over time (Chahal et al., 2023).

Soil texture in the studied forest soils was assessed by genetic horizons. In *A* horizon of the studied Cambisols it varied in the category of loamy soils (Fig. 4), as follows: sandy loam (SP2 and SP8), sandy clay loam (SP4, SP5, SP6, SP7 and SP10) and clay loam (SP1, SP3 and SP9). The sand was found to be the predominant fraction of the *A* horizon in most of the soil profiles. Its values varied in wide range from 26.59% up to 76.72%. Clay was the least abundant fraction. It should be noted that clay content in the surface horizon in two of the soil profiles is above 30%. Based on the results for soil texture of the other soil samples, it can be assumed that this amount was not a result of an in-situ clay formation process. This is a result of the increased amount of organic colloids in the soil samples due to higher humus content (10.82 % in SP1 and 13.83 % in SP6).

The higher amount of sand and silt determines the lower values of bulk density and particle density of the soil and the higher values of porosity in this horizon. Chemically low active fractions of soil texture predominate, which causes the lower content of basic elements and correspondingly low sorption capacity of the soil in *A* horizon.

In the *Bw* horizon, soil texture was more diverse, but sand and silt also predominated. Soil texture in cambic horizon varied in the category of loamy soils (Fig. 5). In SP1, SP6 and SP9 it was assessed as loam, in SP4, SP5 and SP10 - as sandy clay loam, in SP2 and SP8 - as sandy loam, and in SP3 - as clay loam. The content of sand ranged from 33.33% to 76.63%. Clay content was higher in soil depth, and it ranged between 10.69% and 34.08%. The highest value of clay content was found in SP3 (34.08%), which was an exception regarding the results for all other samples. Considering the altitude (942 m a.s.l.) of SP3 and the relevant climatic conditions under which the soil was formed, in situ ongoing intensive clay formation process was not possible. Therefore, the soil cannot be defined as texturally differentiated. A logical explanation could be the flat terrain, which implies the transport of clay particles from the higher parts of the slope for various reasons in the past, such as tree felling, cuttings, uprooting, etc.

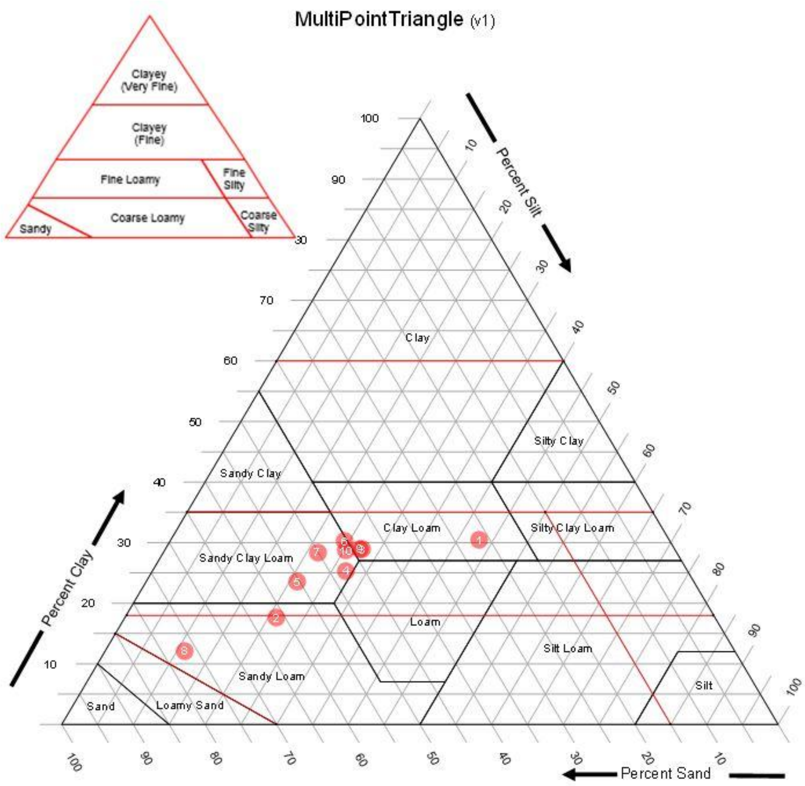

Fig. 4. Soil texture in *A* horizon of the studied soil profiles.

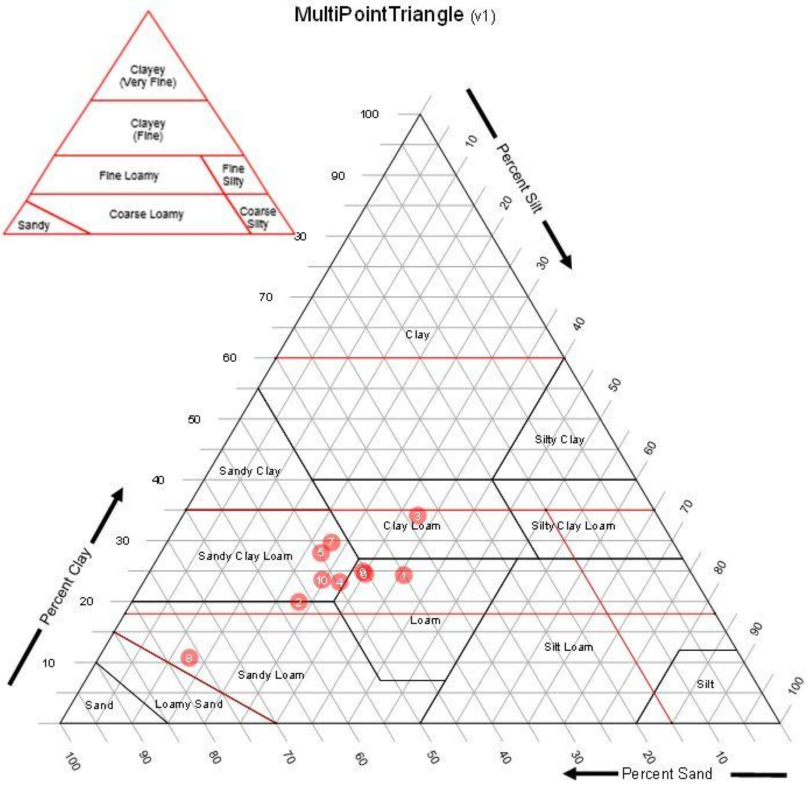

Fig. 5. Soil texture in *Bw* horizon of the studied soil profiles.

To assess soil health status of the studied forest soils, some main soil physical properties were taken into account, such as bulk density, particle density and soil porosity. The results obtained for these indicative soil parameters are shown in Table 2.

Table 2. Main physical properties of the studied soil profiles.

SP	Horizon	Bulk density, g/cm^3	Particle density	Soil porosity, %
1	*A*	0.47	2.33	80
	Bw	0.61	2.62	77
2	*A*	1.11	2.53	56
	Bw	1.39	2.56	46
3	*A*	1.05	2.53	58
	Bw	1.12	2.71	59
4	*A*	0.96	2.42	61
	Bw	0.87	2.49	65
5	*A*	0.72	2.38	70
	Bw	0.92	2.59	64
6	*A*	0.87	2.36	63
	Bw	0.96	2.44	61
7	*A*	0.94	2.39	61
	Bw	0.91	2.56	64
8	*A*	1.31	2.62	50
	Bw	1.72	2.62	34
9	*A*	0.64	2.38	73
	Bw	0.89	2.43	64
10	*A*	0.75	2.30	67
	Bw	0.94	2.49	62

According to the results obtained for bulk density of the forest soil in the studied profiles, it was established that it is ideal for tree rooting system, except for the soil in SP2 (*Bw* horizon) and SP8, where it was highly compacted which restricts the growth of tree root systems. Particle density followed the BD values. The soil porosity values were high (Table 2). The studied soils are considered porous and therefore able to provide sufficient pore space for air and water, which tree roots need.

Organic matter is essential for the soil formation process and therefore it is vital for soil health (Hussain et al., 2023). The organic matter that comes on the soil surface from tree litter fall plays an important role in the composition of humus in *A* horizon. The aboveground litter fall in the studied soil profiles ranged from 1 cm (SP2, SP3, SP5 and SP9) to 2 cm (SP1, SP4, SP6, SP7, SP8 and SP10). It was composed mainly of leaves, twigs, fruits and seeds of common beech. In SP1, SP2, SP3, SP4, SP5, SP8, SP9 and SP10 it was composed of *LF* layer and was defined as a mull type. For SP6 and SP7 the litter fall was composed of two layers - *L* and *FH*.

The pH (H_2O) of the aboveground litter fall was in the acidic range. For *LF* layers it varied between 5.0 (SP10) and 5.7 (SP4). It was assessed as strongly acidic to moderately acidic. The low pH values of the aboveground litter fall highly affected the mineral part and acidified the soil. The depth of *A* horizon varied between 5 cm (SP1 and SP8) and 22 cm (SP10). The content of org. C in it ranged from 18.17 $g.kg^{-1}$ (SP2) to 80.21 $g.kg^{-1}$ (SP1), so it was assessed as low to very high. The average amount of org. C in *A* horizon was estimated to be high. It should be noted that the coefficient of decline is low in the studied profiles, and the amount of org. C gradually decreased in the metamorphic horizon. The coefficient of decline was between 1.44 (SP3) and 2.61 (SP5). The content of humus in *A* horizon of soil profiles varied widely between 3.13% (SP2) and 13.83% (SP1). The content of org. C was assessed as low to high (Vanmechelen et al., 1997). Very high values have been formed at higher altitudes, except for SP1, where a low in depth *A*turf horizon of 757 m a.s.l. was formed. The humus in the *A* horizon was acidic. Decomposition of organic matter was associated with the release of high amounts of acidic products, which formed a very strongly acidic reaction of the soil. The C/N ratio was between 9.0 (very low) and 19.0 (low), with an average of 13.0. According to Funakawa et al. (2006), the stability of carbon in soils is impaired when the pH drops below 4.0. This threshold is considered as critical due to the increase in its mobility. This applies to both the litter layer and the surface *A* horizon. Despite the high acidity of Cambisols, the content of org. C was sufficient and in stable form. Low C/N values indicated relatively rapid transformation of organic matter, both in litter and in the soil profile. The content of total nitrogen in the *A* horizon of the studied soils ranged between 0.952 $g.kg^{-1}$ (SP2) and 6.742 $g.kg^{-1}$ (SP1). These values were assessed as low to very high. The average value for the total nitrogen was 4.0 $g.kg^{-1}$.

The depth of *Bw* horizon was in the range of 33 cm (SP8) up to 48 cm (SP1) and meets the criteria of WRBSR (2006, 2007) for cambic diagnostic horizon. The humus content in *Bw* horizon was in the range of 1.35% (SP8) to 7.13% (SP10), with an average value of 4.92%, which was assessed as high. The content of org. C in cambic horizon varied from very low - 7.84 $g.kg^{-1}$ (SP8) to high - 41.36 $g.kg^{-1}$ (SP10), with an average of 28.50 $g.kg^{-1}$. Total nitrogen varied from very low - 0.463 $g.kg^{-1}$ (SP8) to high - 2.861 $g.kg^{-1}$ (SP1).

The obtained CEC values in *A* horizon were assessed as low (3.9 $cmol(+).kg^{-1}$ in SP2) to high (16.5 $cmol(+).kg^{-1}$ in SP1). For *Bw* horizons their values ranged from low (2.7 $cmol(+).kg^{-1}$ in SP1) to average (5.8 $cmol(+).kg^{-1}$ in SP9). All the studied soils were unsaturated with bases. BS values ranged between 9% and 35% in the *A* horizon, and between 5% and 34% in *Bw* horizon.

The stock of organic matter, the content of total nitrogen, as well as the content of mobile forms of phosphorus and potassium, have been calculated for the effective depth of the soil profiles (*A*+*Bw* horizons) as a stock per hectare (Table 3). The results showed that the soil profiles were shallow, moderately to well stocked with humus and org. C, but low stocked with soluble forms of phosphorus and potassium. Similar results have been obtained for the org. C stock in Europe. According to Baritz et al. (2010), it ranged from 11.3 to 126.3 t/ha for the mineral soil (0–20 cm).

Soil health highly depends also on available water content. For the studied soils, it was assessed that the available water content (%) was moderate to low. According to the values obtained in mm, these soils were classified as dry (Table 4).

The data showed that field capacity in *A* horizon of the studied soils varied in wide range from 21.77% up to 58.13%. The same applied for *Bw* horizons - from 14.15% up to 68.45%. A negative impact on the soil health of the studied soils was indicated by the established high values of permanent wilting point (up to 20.72% in SP1) and therefore the low content of available water, which is critical to maintain good soil health status of the soil.

Table 3. Stock of organic matter, total nitrogen and available potassium and phosphorus.

SP	Soil depth *A+Bw* , cm	Humus	Org. C	Total Nitrogen	P_2O_5	K_2O
		t/ha				
1	53	204.40	118.55	8.74	19.12	160.19
2	46	128.52	74.54	4.08	63.26	248.40
3	50	184.95	107.27	9.63	64.99	273.07
4	43	267.44	155.12	10.58	23.91	314.64
5	50	144.41	83.76	6.86	25.22	142.09
6	50	312.54	181.27	11.02	78.04	206.39
7	55	279.66	162.20	10.64	80.53	261.14
8	38	80.18	46.50	3.00	28.46	175.52
9	43	199.99	115.99	10.30	73.81	166.96
10	63	469.85	272.51	19.61	153.75	211.19

Table 4. Main water properties of the studied soils.

SP	Horizon	Field capacity, %	Hygroscopic moisture, %	Permanent wilting point, %	Available water content, %	Available water content, mm
1	*A*	53.95	15.47	20.72	33.22	7.28
	Bw	68.45	11.01	14.75	53.70	136.19
2	*A*	30.82	16.90	3.82	5.12	11.78
	Bw	27.07	21.46	4.12	5.53	15.93
3	*A*	25.67	8.18	10.96	14.71	12.65
	Bw	28.02	8.66	11.60	16.41	50.07
4	*A*	35.55	11.85	15.87	19.68	17.91
	Bw	47.00	9.07	12.15	34.85	95.69
5	*A*	37.26	10.13	13.57	23.69	16.47
	Bw	40.21	8.28	11.10	29.11	101.62
6	*A*	36.36	10.74	14.39	21.97	13.46
	Bw	44.62	9.66	12.95	31.67	119.11
7	*A*	29.92	9.21	12.34	17.58	15.86
	Bw	42.97	8.17	10.95	32.02	103.67
8	*A*	21.77	2.65	3.55	18.23	9.93
	Bw	14.15	1.45	1.95	12.21	55.76
9	*A*	52.40	12.17	16.31	36.10	12.21
	Bw	48.58	11.02	14.76	33.81	98.85
10	*A*	58.13	13.72	18.38	39.75	63.98
	Bw	46.56	12.49	16.74	29.83	105.11

Conclusions

Based on the results obtained for the main indicative parameters of the studied soils and their assessments, it can be pointed out that low pH, low clay content, low CEC and low BS values are considered as main prerequisites for the deterioration of soil health status. It was established that the advanced acidification process throughout the soil depth poses a major risk to the health of these soils. Due to the acidification, low CEC and BS of these soils, as well as some significant anthropogenic pressure and climate changes, these processes need to be monitored over time. Despite the shallow soil profiles and low to moderate water content of the studied Cambisols, they are rich in humus and at this stage of their development can offer suitable growing conditions for common beech stands in Petrohan area.

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