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Original Paper

Spatial variability in chemical properties of eutric cambisol

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This work is oriented on evaluation of the impact that relief has on different values of various chemical parameters of Eutric Cambisol as well as on determination of the correlation between observed soil properties. The soils samples were collected in the autumn of 2011 in the central part of Slovakia, on the neovulcanites of the Kremnica Mountains (Central Slovakia). We determined the soil reaction (pH), the total content of organic carbon and humus, the content of labile carbon, the content of potentially mineralizable nitrogen, the content of inorganic forms of nitrogen, the sum of basic cations, the cation exchange capacity, hydrolytic acidity and base saturation. The values of soil pH in the monitored soil type were in the range from 6.3 to 7.2, the content of humus was in the range from 1.51 to 6.76 %, the ratio of labile forms of carbon and nitrogen in the range from 15.53 to 80.92. When observing the content of nitrate nitrogen and ammonium nitrogen in soil samples, we found out that the content of nitrate nitrogen was 1.5 times (54.5 %) higher on the slope and 1.1 times (10.5 %) higher on the plain than the content of ammonium nitrogen. In our statistical evaluation of the variability of soil chemical parameters with regard to the selected types of relief (plain, slope), we found a significant difference between the contents of organic carbon ($p = 0.021$) and also the contents of labile forms of carbon and nitrogen. The values of soil chemical parameters were affected by the relief shape as well as by a higher level of groundwater. In the soil samples, a positive relationship was found between the content of organic carbon and the labile form of nitrogen ($r = 0.747$; $p < 0.01$). We also determined a positive correlation between the content of labile forms of carbon and nitrogen ($r = 0.600$; $p < 0.05$).

Keywords: arable soils, Eutric Cambisol, chemical properties, Kremnica Mountains, georelief

1. Introduction

The characteristics of soil are influenced by human activity, climate changes, fertilization, and the way of farming as well as spatial relationships in the country. According to Miklós (1997), the main indicator of space and location in the country is the relief. Georelief affects other elements of the geosystem in a large extent (Miklós a Špinerová, 2010) and it also impacts physical and biological characteristics of soil. Complex health conditions of the soil, its chemical, physical and biological characteristics are influenced by the organic substance (Haynes, 2005). The content of soil organic carbon is one of the most important indicators of soil quality (Campbell et al., 1996; Brejda et al., 2000), it helps to increase the production capability of soil (Allison, 1973) and it contributes to environmental protection (Thang et al., 2010). Soil organic substance is the main attribute of soil that determines its production capacity (Robinson et al., 1994) and its quality (Doran and Parkinm 1994; Haynes, 2005).

Cultisoil is a type of soil found on natural substrates but with changed characteristics caused by human activity mainly during agricultural utilization. There is a large amount of information about soil characteristics that have been influenced by the natural ecosystem changes and they have evolved into agroecosystems (Szombathová et al., 2001; 2010) or even urban agroecosystems (Szombathová et al., 2004; Tobiašová, 2010). The most common soil type in Slovakia that could be changed into cultisoil is cambisol. Cambisol belongs to the group of brown soils and it represents the most widespread soil in Slovakia (Bielek et al., 1998). Its pedogenic substrates include the mantle of eruptive volcanic rocks and non-carbonate unpaved sediments as well as carbonate rocks (Bielek et al., 1998). Cambisol can be characterized by its typical weak or medium weathering of maternal material and the absence of remarkable amount of illuvial clay, organic substance, Al and/or Fe elements (Sobocká, 2007; WRB, 2006). The B horizon is dominant in this soil type. It has a more expressive brown colour than the C horizon. This is caused by the browning process (releasing of Fe from the primary silicate) and the process of secondary mineral formation (Bielek et al., 1998). The content of humus in cambisol differs. According to Sobocká (2007), cambisols are suitable for agriculture and on undulating or hilly terrain, annual or perennial plants are grown.

The aim of this work was to summarize the impact of the relief on the difference in cambisol chemical parameters and to determine the correlation relationships between soil chemical characteristics.

2. Material and methods

The analyzed soil samples were taken from cadastral land of the village Jastrabá (48° 37´ 59.16´´ E; 18° 55´ 59.88´´ N) in the Kremnica Mountains from arable soil (land parcel

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281/2, 282/1, 703/2) used for growing potatoes (*Solanum tuberosum* L.). The samples were taken in the autumn of 2011 in the form of test – pits (Tab. 1). The basic colour of horizons as well as the brightness and richness of colour were determined according to standardized charts (Munsell Soil Colour Charts, 2009).

Soil samples were repeatedly taken from different depths (0.0 to 0.1 m; 0.1 to 0.2 m, 0.2 to 0.3 m; 0.3 to 0.6 m) on four fields. Soil sampling was followed by repeated analyses (Tab. 2).

In the dried and sieved soil samples, these parameters were determined: soil reaction (active and exchange), total organic carbon (TOC), labile carbon (C_L), potentially mineralizable nitrogen (N_L), inorganic nitrogen (N_{in}), cation exchange capacity ($CEC = H + S$), base saturation ($V = S/CEC \times 100$), hydrolytic acidity (H) and the sum of basic cations (S). Soil samples were chosen by standard procedures:

- soil reaction – the ratio of soil : solution was 1 : 2.5 (Fiala et al., 1999),
- active soil reaction (pH_{H2O}) – potentiometric method in distilled water,
- exchange soil reaction (pH_{KCl}) – potentiometric method in a solution of 1 mol dm^{-3} KCl,
- total organic carbon (TOC) – oxidometric method by Thurin modified by Nikitin (Orlov a Grišina, 1981),
- the content of humus was counted from the content of the organic carbon as Humus = TOC × 1,724,
- labile carbon (C_L) – oxidation with $KMnO_4$ (Loginov et al., 1987),
- potentially mineralizable nitrogen (NL) – (Standford and Smith, 1978),
- inorganic nitrogen (Nin) = ($N\text{-}NH_4^+ + N\text{-}NO_3^-$) – (Radov et al., 1985),
- cation exchange capacity (CEC) and the sum of basic cations (S) – according to Jackson (2005).

The measured data was statistically processed with the SPSS software, a statistics program using non-parametric tests. The Mann-Whitney test was used to compare the attributes of chemical parameters determined on chosen relief types (plain, slope). To determine the correlation relationships between chemical parameters was used Spearman's test of serial correlation.

3. Results and discussion

The quantity and quality of organic substance is determined by the content of total organic carbon (Kubát et al., 2006). The values of total organic carbon content (TOC) in the soils located on slopes were in the range of 1.24–3.92 % and in the soils located on plains, these values were in the range of 0.88–2.85 %.The humus content in chosen soil was in the range of 1.51–6.76 % (Tab. 3). Labile pools of organic substance are important because they regulate the productivity of ecosystems in short time intervals and they are influenced by the way of farming (Jandl and Sollins,

Table1 Morphological description and identification of soil horizons

Identification	Depth	Characteristics
Slope – Eutric Cambisol KMa		
Akp	0.0–0.3 m	A-horizon of Anthrosols with signs of cultivation, damp, loose, micro-lumpy structure, without coating and neologism, colour by wet 10 YR 2/2
Bv	0.3–0.6 m	brown B-horizon of Cambisol, moist, loamy, polyhedral structure, without coating and neologism, colour by wet 10 YR 3/2
C	> 0.6 m	diluvium on the sandy substrates, damp, cohesive, loamy, colour by wet 10 YR 4/3
Plain – Stagni-Eutric Cambisol KMag		
Akp	0.0 – 0.3 m	A-horizon of Anthrosols with signs of cultivation, damp, loose, grained-polyhedral structure, without coating and neologism, colour by wet 10 YR 2/3
Bv	0.3 – 0.6 m	brown to reddish brown B-horizon of Cambisol, with hints of hydromorphic properties, moist, loamy, polyhedral structure, without coating and neologism, colour by wet 10 YR 3/3
Cg	> 0.6 m	cohesive clay-loam diluvium with signs of gleyic properties, loamy sand with an admixture of gravel (up to 10 %), wet, loamy, featureless structure, reddish brown coating on the sand grains, colour by wet 2.5 YR 5/4

Table 2 Characteristics of the soil sampling sites

Parcel number	Altitude (MASL)	Position	Orientation	Relief slope	Cadastral territory	Geomorphologic division
281/2a	404	slope	SW/W	7–12°	Jastrabá	Jastrabská vrchovina Mts.
282/1	403	slope	SW/W	7–12°		
281/2b	392	plain	SW/W	<3°		
703/2	376	plain	E/SE	<3°		

Table 3 The values of soil chemical properties on different types of georelief

Typesof relief	**Parcel number**	**Depth in m**	**pH$_{H2O}$**	**pH$_{KCl}$**	**TOC**	**Humus**	**C$_L$**	**N$_L$**	**C$_L$: N$_L$**	**N-NO$_3^-$**	**N-NH$_4^+$**	**N$_{in.}$**	**H**	**S**	**CEC**	**V**
					%		**mg kg^{-1}**			**mg kg^{-1}**			**mmol kg^{-1}**			**%**
Slope	281/2a	0.0-0.1	6.8	6.5	2.99	5.16	5742.03	191.42	30.00	18.6	9.3	27.9	35	309	344	94
	281/2a	0.1-0.2	6.8	6.4	2.70	4.66	4383.43	167.41	26.18	16.1	9.1	25.2	26	312	338	91
	281/2a	0.2-0.3	6.7	6.4	1.24	2.14	1354.94	155.45	24.72	11.5	7.1	18.6	75	224	299	65
	281/2a	0.3-0.6	6.7	6.4	2.27	3.92	2241.14	144.28	15.53	7.8	6.6	14.4	68	243	301	62
	282/1	0.0-0.1	6.8	6.4	3.16	5.45	5548.50	96.39	57.56	12.4	7.3	19.7	12	323	335	95
	282/1	0.1-0.2	6.8	6.4	2.63	4.54	5270.71	76.74	68.68	10.8	7.0	17.8	15	306	321	92
	282/1	0.2-0.3	6.7	6.3	3.92	6.76	4155.93	51.36	80.92	9.1	7.7	16.8	13	314	327	90
	282/1	0.3-0.6	6.6	6.3	3.09	5.33	3407.00	42.35	80.45	9.1	7.2	16.3	108	197	305	63
Average values			**6.74**	**6.39**	**2.75**	**4.75**	**4012.96**	**115.68**	**48.01**	**11.93**	**7.66**	**19.59**	**44**	**278.5**	**321.25**	**81.5**
Plain	281/2b	0.0-0.1	6.4	6.2	2.00	3.45	3918.47	119.93	32.67	10.6	8.3	18.9	54	264	318	84
	281/2b	0.1-0.2	6.3	6.0	2.04	3.51	3466.33	96.03	36.1	14.8	10.0	24.8	97	194	291	61
	281/2b	0.2-0.3	6.3	6.0	0.88	1.51	2788.84	95.99	29.05	8.1	7.6	15.7	176	143	319	45
	281/2b	0.3-0.6	6.3	6.0	2.85	4.92	5264.75	65.39	80.51	6.5	7.8	14.3	148	152	300	53
	703/2	0.0-0.1	7.2	6.7	1.88	3.25	1281.68	25.51	50.24	8.6	7.5	16.1	72	253	325	84
	703/2	0.1-0.2	7.2	6.5	1.94	3.35	1272.46	25.44	50.02	8.0	7.2	15.2	31	298	329	83
	703/2	0.2-0.3	7.0	6.5	1.71	2.95	1022.02	17.74	57.61	5.0	6.1	11.1	123	214	337	63
	703/2	0.3-0.6	6.6	6.4	1.32	2.28	1080.02	16.97	63.64	5.3	6.0	11.3	168	172	340	48
Average values			**6.66**	**6.29**	**1.83**	**3.15**	**2511.82**	**57.88**	**49.98**	**8.36**	**7.56**	**15.93**	**108.63**	**211.25**	**319.88**	**65.13**

1997). In the profile of cambisol in the land parcel 281/2b was the higher value of labile carbon content and the ratio of labile forms of carbon and nitrogen in Bv horizon in the depth 0.3–0.6 m as in Akp horizon (Tab. 3). The ratio of labile forms of carbon and nitrogen in the soils located on slopes was in the range from 15.53 to 80.92 and in the soils located on plains, it was in the range from 29.05 to 80.51 (Tab. 3). Zaujec and Kobza (2002) state that the rates of $C_L : N_L$ ratio in Slovak soils can reach the values from 6.39 to 72.10. According to Grignani et al. (2007), the fractions of carbon and nitrogen are used as indicators of continuous soil fertility in agroecosystems.

According to Koleda et al. (2012), relief slope is the main factor of trailing ratio influencing the direction of water outflow and soil elements on the slope. This indicator is important for qualification of the diffusion or concentration of the elements in a particular place. When comparing the rates of soil chemical parameters, a higher average content of chemical parameters was determined in slope soils (parcel number 281/2a, 282/1) than in plain soils (parcel number 281/2b, 703/2) (Tab. 3). Lower rates of some parameters (TOC, humus) in plain soils could be caused by the high level of groundwater on parcels number 281/2b and 703/2. The level of groundwater can influence the biochemical reaction of decomposition and its slowdown, mineralization and humification, as spare amounts of humidity create anaerobic conditions influencing the process of humification, which is connected with the determined lower humus content (1.51–4.92 %) in plain soils when compared to the humus content (2.14–6.76 %) in slope soils (Tab. 3) According to Brady and Weil (1999), fast decomposition and mineralization of organic remains in soil happens under optimal conditions for the activity of microorganisms that take part in this process. Microbial activity does not only influence mineralization of fresh organic remains and formation of new humus substances, it also influences stabilization and mineralization of older humus reserves (Stevenson, 1994).

The values of nitrate nitrogen are negatively influenced by abnormal water amounts as this moving form of inorganic nitrogen can easily drift out. We determined a statistically significant difference in the content of nitrate nitrogen on various relief types ($p = 0.036$) on the importance level of $\alpha = 0.05$ (Tab. 4).

Smatana (2001) states that the content of nitrate nitrogen in brown soil (Malanta) is two or five times higher than the content of ammonium nitrogen. Compared with the rates of ammonium nitrogen, the content of nitrate nitrogen we determined in cambisol was 1.5 times higher (54.5 %) in the samples taken from the slope and 1.1 times higher in the soil samples taken from the plain (Tab. 3). Lower rates of nitrate nitrogen on the plain were influenced by drifting in the soil profile (Tobiášová a Šimanský, 2009). According to Paula and Clark (1989), the temperature and humidity of soil as well as the structure determining the water and air regime of the soil have a remarkable influence on the nitrification process.

Ammonium nitrogen is the substrate for nitrate bacteria in the first phase of nitrification. The soil samples were taken a month after the potatoes which caused soil aeration supporting the nitrification process. According to Smatana (2001), agrotechnical methods (cultivation, crop rotation) influence the production of nitrates in the soil. The changes in inorganic nitrate form content in the soil are not only connected with the amount of applied nitrogen, they result

Table 4 Analysis of variance of soil chemical parameters depending on the relief shape

Chemical parameters	**Test statistics**	**Significant level**
pH H_2O	-0.800	0.424
pH KCl	-0.489	0.625
TOC	-2.310	0.021*
Humus	-2.310	0.021*
C_L	-1.995	0.046*
N_L	-2.100	0.036*
$C_L : N_L$	-0.420	0.674
$N\text{-}NO_3^-$	-2.102	0.036*
$N\text{-}NH_4^+$	-0.158	0.875
N_{in}	-1.890	0.059
H	-2.310	0.021*
S	-2.310	0.021*
CEC	-0.315	0.753
V	-2.261	0.024*

* $p < 0.05$

Table 5 The correlation between the parameters of carbon and nitrogen and the parameters of sorption complex and soil reaction

	pH_{H2O}	pH_{KCl}	H	S	CEC	V
TOC	0.040	-0.134	-0.600*	0.571*	0.109	0.551*
Humus	0.040	-0.134	-0.600*	0.571*	0.109	0.551*
C_L	-0.146	-0.293	-0.535*	0.488	0.038	0.579*
N_L	-0.142	-0.147	-0.356	0.347	-0.156	0.378
$N\text{-}NO_3^-$	0.049	-0.046	-0.559*	0.547*	0.022	0.646**
$N\text{-}NH_4^+$	-0.284	-0.384	-0.196	0.185	-0.100	0.232
N_{in}	-0.018	-0.079	-0.571*	0.565*	0.035	0.651**
$C_L : N_L$	-0.033	-0.138	0.000	-0.024	0.106	0.018

** $p < 0.01$ * $p < 0.05$

from the relations between the quality and quantity of soil organic substance, soil parameters and conditions of microbial process (Bielek, 1984, 1998; Demo, 1990; Décau et al., 1994; Ivanič and Pačuta, 1988; Ondrišík et al. 1998; Paul and Clark, 1996).

Considering the statistically determined variability of soil chemical parameters based on the chosen types of relief (plain, slope), we have determined an important difference between the contents of organic carbon (p = 0.021) as well as the contents of labile forms of carbon and nitrogen on the level of importance α = 0.05 (Tab. 4). The relief shape had statistically significant influence on the sorption characteristics of soil. In slope soils, the average content of the sum of basic cations was 278.50 mmol kg^{-1} and in plain soils, the content of basic cations was 211.25 mmol per kg (Tab. 3). The lower content of removable basic cations was caused by the relief shape and the level of groundwater (Tab. 3). Chemical indicators of soil do not only influence external environmental factors, there is an interaction between them as well. We were testing the correlation relationships between particular soil chemical indicators (Tab. 5).

Nitrification is markedly influenced by the soil reaction (Kemmitt et al., 2006). Positive relations were found between the organic carbon content and the content of labile forms of nitrogen in the soil (r = 0.747; p <0.01), as stated by Powlson et al. (1987). According to statistical data, we found a dependence between the content of labile forms of nitrogen and carbon (r = 0.600; p <0.05). Huang et al. (2008) detected a similar interactive dependence between the pools of labile organic carbon and the pools of labile organic nitrogen and they pointed out the similarity of these pools.

The level of sorption capacity saturation with base saturation was in a positive correlation with the content of labile carbon (r = 0.579; p <0.05) (Tab. 5). However, labile carbon was also in a negative correlation with the hydrolytic acidity (r = -0.535; p <0.05) (Tab. 5), while Tobiášová (2010) determined a positive correlation (r = 0.441; p <0.05). There was a negative correlation between the total of organic carbon and hydrolytic acidity (r = -0.600; p <0.05) (Tab. 5).

4. Conclusions

A significant difference in the variability of values in different kinds of relief was determined in labile forms of carbon and nitrogen. The highest average content of labile forms of carbon and nitrogen was detected in the cambisol on the slope. The relief shape influenced the rates of nitrate nitrogen in the soil.

The content of labile carbon in the soil was in a positive correlation with the content of the total organic carbon in the soil (r = 0.747; p <0.01). There was also a positive correlation between labile forms of carbon and nitrogen (r = 0.600; p <0.05).

The evaluation of relief influence on the variability of soil chemical parameters represents an important factor when choosing suitable agricultural plant in a particular locality. That is why in practice, it is always necessary to consider the actual chemical characteristics of arable soil influencing its production abilities.

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