Comparison of the andosols properties of forest and meadow ecosystems on the neovolcanic rocks of the Central Slovakia

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Abstract

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The aim of the paper was to describe the chemical and physical characteristics of the mixed forest soils and to compare their characteristics with meadow soils (mowed and xerothermic) situated at selected volcanic mountains of Central Slovakia. The andosols analysed were taken from the Kremnické and the Štiavnické mountains. The chemical and physical characteristics of andosols have been monitored. It was proved that in the mixed forests there is a constant input of fresh organic matter which affects the content of total organic carbon (TOC) and keeps it at a steady level. The highest value variability of TOC among seasons and the highest average value of TOC were proved to be in xerothermic meadows (8.93 ± 4.49%). The land use has a statistically significant impact on the differences between the values of active pH ($F = 7.5001$, $p = 0.001$) and exchangeable soil reaction ($F = 18.8866$, $p = 0.000$). Total nitrogen (N_T) was affected by land use and was decreasing from xerothermic meadows to mixed forests ($p < 0.001$) in linear dependence similar to the TOC content ($F = 11.7573$, $p = 0.000$). The value variabilities of cation exchange capacity (CEC) and basic cation (S) between soils of mixed forest and mowed and xerothermic meadows were statistically significant. The content of TOC negatively correlated with the sand fraction (soils of the mixed forest and xerothermic meadow) and the clay fraction (soils of monitored ecosystems).

Key words

andosols, ecosystem, Kremnické and Štiavnické mountains, season, soil properties

Introduction

Andosols represent a unique body of soil types in Slovakia that is part of the national heritage. Moreover, they are part of European volcanic soils (Juráni and Balkovič, 2007). The genesis of andic properties and characteristics is determined by the natural soil-forming factors in the following order: rock-time-climate-relief-vegetation (Balkovič, 2002). The soils formed from volcanic materials, which contain a large amount of soil organic carbon (SOC) due to their stabilization, belong to mineral soils (Armas-Herrera, 2012; Mora et al., 2014). Andosols have a specific morphology and specific physical and chemical properties (Novak et al., 2010). Andosols are soils with a large structural development and stability of aggregates. Their properties have a significant role in their high infiltration rate. However, they are affected by environmental changes,

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especially those related to changes of land use (Neris et al., 2012). The land use in practice can have a permanent effect on the distribution of nutrients in soil, and it can affect the natural recovery of the ecosystem at the end of the land use (Lal, 2000; Aleksandrowicz-Trzcińska, 2005; Sakbaeva et al., 2012, Gömöry et al., 2015). Generally, the soils used for agriculture are not similar in terms of the chemical, physical and biological characteristics compared to forest soils (Małecka and Hilszczańska, 2014).

It is important to monitor not only the changes in the land management and landscape cover, but also the content of soil organic matter. It has ecological and environmental consequences (Slepetienė et al., 2010; Hudec and Hreško, 2012). Soil organic matter (SOM) is a determining factor of soil quality (Ryan, 1998; Gärdenäs et al., 2011; Ostrowska and Porębska, 2012). It has an important role in the soils of each ecosystem (Kalisz et al., 2010). It affects the chemical and physical properties of soil, such as the formation of stable aggregates, water retention, cation exchange capacity, nutrient content as well as nitrogen and carbon content (Kononova, 1966). Arrouays et al. (2001) and Navarrete et al. (2010) reported that the carbon cycle, biodiversity and soil fertility are influenced by land management, landscape cover and agriculture. In forest management, the soil has an important role, especially in the production of plant biomass. Sand density affects its structure, and can lead to changes of biomorphological characteristics (Pach et al., 2001), changes of biomass allocation (Jagodziński and Oleksyn, 2009a) and it can modify the retention of nutrients in biomass and soil (Jagodziński and Oleksyn, 2009b; Małecka and Hilszczańska, 2014). Soil organic matter is very important to all soil processes that have an impact on crop production and the environment (Ryan et al., 2008). The soil carbon losses from soil cause the reduction of organic matter, fertility, ability to retain water and frequent local dryness (Bierkens et al., 2008).

In recent years, the number of changes in the country has been increasing, which represents a risk for accumulation of carbon in the forest in terms of time and area. The type of vegetation cover of non-cultivated land is a factor that affects the organic carbon content of soil (Liu et al., 2010). Soil organic components are important factors of forest health and productivity (Jurgensen et al., 1997). The losses of forest cover affect the decrease of the SOC which occurs in advance of complete deforestation when degraded forests are transformed into pasture, cropland and eroded areas (Covaleda et al., 2011).

The aim of this study was to observe changes of the chemical and physical characteristics of the andosols soil type. Soil samples were collected from selected ecosystems (mixed forest, meadows: mowed and xerothermic) in different seasons (autumn, spring) during 2011–2013.

Material and methods

The study was located in Kremnické and Štiavnické mountains (Fig. 1). Kremnické and Štiavnické mountains are volcanic mountains that are located in Central Slovakia. It is part of the West Carpathians province, sub-province Inner Western Carpathians and the Slovak Central Mountains. It is important to define the correct position with respect to individual monitoring points for the sampling of soil. Soil samples were collected by a probe (10 sampling sites = 10 open borrow pits) from a depth of about 1 m in autumn of 2011, 2012 and spring of 2012, 2013. An open probe is used for determination of soil characteristics such as soil profile description, its depth, the stratigraphy (arrangement of genetic horizons) and morphological characteristics. A soil sample was taken from each sampling area (5 × 5 m) in a total of ten different locations (Table 1).

The sampling area was divided into regular grids. This provides a balanced surface covering of the land being surveyed and contributes to the achievement of objective results (Nozdrovický, 2008). The soil samples were taken from the terrestrial organogenic horizon Ol (0–5 cm), Aau horizon (5–35 cm) and from Bva cambic andosols horizon (35–60 cm). Andosols were identified according to IUSS Working Group WRB (2006), on the basis of the dark-coloured, deep, fluffy, melanic, andic (Aa) horizon. Allophanes and grain size of soils were not evaluated.

Soil was air-dried at room temperature and sieved (<2 mm), and a sample was taken using standard procedures. Visible plant remnants were removed by hand. Soil reaction was determined in distilled water as active soil reaction (pH_{H2O}) and in a solution of 1 mol L^{-1} KCl as exchange soil reaction (pH_{KCl}). The ratio of soil and solution was 1 : 2.5 (van Reeuwijk, 2002). Total organic carbon (TOC) was measured using the Tjurin method modified by Nikitina according to Orlov and Grišina (1981). The content of humic substances (HS), as well as the HA : FA ratio was determined by group composition of humic substances using the Belčiková-Kononová method (Kononová and Belčiková, 1962). Humic substances were extracted into a 0.1 mol L^{-1} solution of sodium pyrophosphate adjusted to pH = 13 with 1 mol L^{-1} sodium hydroxide and the samples were left for infusion for 24 hours at room temperature. To separate fulvic acids (FA) from humic acids (HA), the solution was centrifuged (10,000 rpm) and the precipitate containing HA was dissolved with sodium hydroxide. The total nitrogen (N_T) was determined by the Kjeldahl method (Bremner, 1960), inorganic nitrogen (N_{in}) as the sum of ammonium ($N\text{-}NH_4^+$) and nitrate ($N\text{-}NO_3^-$), while nitrogen was determined by the colour method (Radov et al., 1985). Cation exchangeable capacity (CEC = H + S), base saturation (V = S / CEC × 100), hydrolytic acidity (H) and sum of basic cations (S) were measured according to Jackson (2005). Silt, sand and

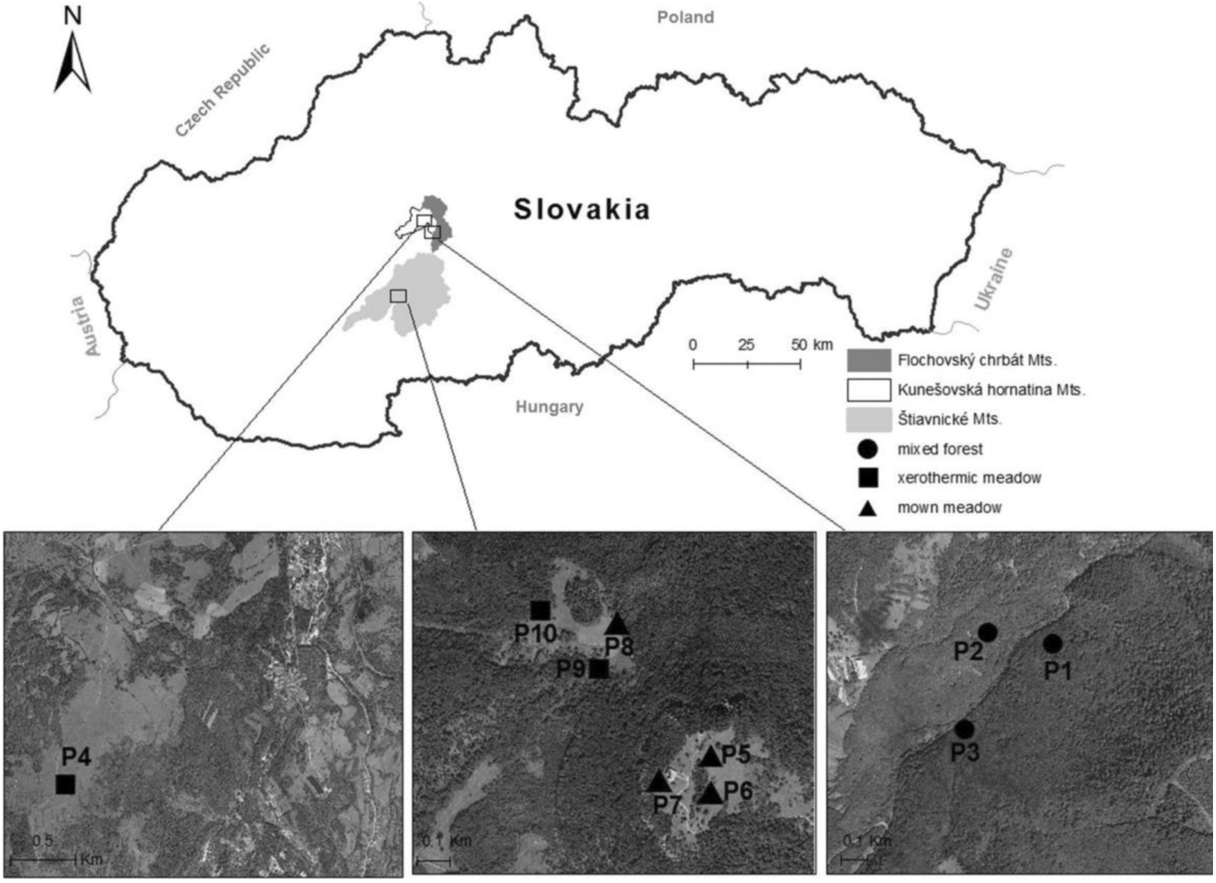

Fig. 1. Localization of the andosols soil type.

Table 1. Characteristics of monitoring places of soil samples

Localization of andosols	Altitude (m o. s.)	Exploitation	Slope exposure	Slope of relief	Outflow conditions	Geomorphological division	
P1	678	Mixed forest	NW	≥25°	Strong outflow	Flochovský chrbát Mts.	Kremnické mountains
P2	637	Mixed forest	SE	≥25°	Strong outflow		
P3	558	Mixed forest	NW	≥25°	Strong outflow		
P4	944	Xerothermic meadow	S	12°–17°	Poor outflow	Kunešovská hornatina Mts.	
P5	1,002	Mown meadow	SE	12°–17°	Moderately strong outflow	Sitnianska vrchovina Mts.	Štiavnické moutains
P6	974	Mown meadow	SE	12°–17°	Poor outflow		
P7	998	Mown meadow	S	7°–12°	Poor outflow		
P8	911	Mown meadow	E	7°–12°	Moderately strong outflow		
P9	891	Xerothermic meadow	SW	≥25°	Strong outflow		
P10	895	Xerothermic meadow	SE	12°–17°	Poor outflow		

E, east; NW, north-west; S, south; SE, south-east.

clay fractions were determined using the pipette method (van Reeuwijk, 2002). The results are shown in the tables by averages from a depth of 0–60 cm.

The measured data was statistically processed using the software Statistics 8, a statistics program using parametric tests. The two-way anova with interaction was used to compare the chemical and physicochemical properties of soil in terms of different seasons and ecosystems, with separation by means of Tukey's HSD test. To determine the correlation relationships between chemical parameters, we used Spearman's test of serial correlation.

Phytocenological research was realized during the years 2013 and 2014 based on the methods developed by the Zurich-Montpellier school (Braun-Blanqet, 1964) using the new Braun-Blanqet 9-member ordinal scale of coverage (Van der Maar, 1978). Bryophytes and lichens were not described. The sampling and described area was 5 × 5 m. Phytocenological records were saved in database software called Turboveg (Hennekens and Schaminée, 2001) and subsequently exported into the software JUICE (Tichý, 2002). For the classification of the entries, Twinspan (Hill, 1979) was also used in the software JUICE (Tichý, 2002) and the formally defined syntaxes in the work of Janišová et al. (2007). The names of taxa are listed according to the work of Marhold (1998). Syntax nomenclature is given by Jarolímek et al. (2008).

P1 – mixed forest, beech-spruce-hornbeam forest (age 150 years; cover crop; stand 285 B) 50% *Abies alba*, 45% *Fagus sylvatica,* 5% *Acer pseudoplatanus*

P2 – mixed forest, beech-spruce-hornbeam forest (age 140 years; cover crop; stand 347 B) 90% *Fagus sylvatica,* 10% *Abies alba*

P3 – mixed forest, beech-spruce-hornbeam forest (age 55 years; cover crop; stand 283 B) 70% *Fagus sylvatica,* 10% *Acer pseudoplatanus*, 10% *Abies alba*, 10% *Picea abies*

P4 – acid loving mesophilic meadow e. g. *Arrhenatherion elatioris,* mowed

P5 – mesophilic meadow e. g. *Arrhenatherion elatioris*

P6 – coppice with transient character, where the species overlap mesophilic meadows e.g. *Arrhenatherion elatioris* and sub-xerophylic lawns for example *Bromion erecti*

P7 – mesophilic meadow e. g. *Arrhenatherion elatioris*

P8 – mesophilic meadow e. g. *Arrhenatherion elatioris*

P9 – coppice with transient character, in which the elements of thermophilic hems grow, for example *Geranion sanguinei,* sub-xerophylic lawns for example *Bromion erecti,* or species of mesophilic meadows *e. g. Arrhenatherion elatioris,* mowed

P10 – ecotonic ecosystem *e. g. Geranion sanguinei,* mowed

Results and discussion

The chemical and physical characteristics of soils under different land uses are shown in Tables 2a–c. The highest average value of total organic carbon (TOC) was detected on xerothermic meadows (8.93 ± 4.94%) in autumn 2011, with the highest values of difference in this land use situation (Fig. 2). The lowest difference in terms of TOC values, between the periods in which soil was sampled, was detected in mixed forest (Fig. 2). The content of TOC in the mown meadow soil showed increasing values during the entire period from autumn 2011 to autumn 2012. In the spring of 2013, there was a decrease of TOC content from 7.42 ± 6.01% to 5.15 ± 3.00%. The TOC content in the soils of the mixed forest and the xerothermic meadow decreased in spring 2013 but not in the same season in 2012.

The TOC content in soil was influenced not only by land use. According to Martellotto (2010), climate affects plant growth and yield, and it mediates decomposition rates, thus impacting on the quantity and rate of C cycling. Management practices will alter this balance by affecting the system's productivity, and the speed of residue and soil organic matter decomposition. The TOC content of forest soils is lower than that of other land use types. It is said that the enrichment of afforested soils by organic substrates in the form of compost and mining residues on the one hand improves the fertility of the poor soils, but on the other hand it stimulates beneficial microbial processes in the environment, increases the proportion of antagonists and also the resistance to infection in the roots of a young forest ecosystem (Kwaśna et al., 2000, 2001).

The central European forestry has started an ecologically-oriented conversion of spruce monocultures to broadleaf and mixed forests (Galka et al., 2014). We monitored the soils of a mixed forest of beech-spruce-hornbeam. With regard to the seasonal impact (autumn/spring), we did not detect statistically significant differences in TOC content ($F = 2.8697$, $p = 0.095$). According to Islam and Weil (2000), the total C (TOC) levels tended to be higher in reforested and grassland sites, but the variability was not high enough. Even Gündoğan et al. (2011) did not detect statistically significant differences in TOC between grassland, forest and arable land. Mutsotso and Muya (2008) also detected a higher TOC content on natural grassland, as well as on natural forest. Changes in TOC content were influenced by different factors and had divergent behaviour depending on the type of habitat and the stand density. In forests, the dynamics of the density are dependent on the species, the quality of the locality (in terms of soil), and other factors (Socha

Table 2a. Mixed forest – average values of soil chemical properties (mean value ± standard deviation)

Chemical properties		2011	2012		2013
		Autumn	Spring	Autumn	Spring
TOC	(%)	4.91 ± 1.86	4.30 ± 2.06	3.99 ± 1.59	3.91 ± 1.84
pH_{H2O}		5.82 ± 0.46	5.97 ± 0.28	6.14 ± 0.07	5.93 ± 0.35
pH_{KCl}		4.73 ± 0.30	5.06 ± 0.40	4.68 ± 0.09	4.84 ± 0.47
$N\text{-}NH_4^+$	$(mg\ kg^{-1})$	13.03 ± 3.38	19.75 ± 4.27	16.70 ± 3.21	14.23 ± 3.33
$N\text{-}NO_3^-$		8.07 ± 2.15	9.13 ± 2.58	8.57 ± 1.84	9.03 ± 1.48
N_{in}		21.10 ± 4.59	28.88 ± 6.82	25.27 ± 4.75	23.27 ± 4.68
N_T		4.13 ± 1.92	3.43 ± 2.12	2.90 ± 1.44	3.12 ± 1.82
HS	(%)	4.45 ± 0.85	3.67 ± 1.07	3.60 ± 0.89	3.27 ± 0.60
HA		1.95 ± 0.45	1.56 ± 0.41	1.65 ± 0.39	1.47 ± 0.32
FA		2.49 ± 0.43	2.11 ± 0.68	1.95 ± 0.50	1.80 ± 0.29
HA : FA		0.78 ± 0.10	0.76 ± 0.12	0.85 ± 0.03	0.82 ± 0.07
C : N		12.51 ± 1.48	13.92 ± 2.63	14.45 ± 2.00	14.48 ± 1.77
H	$(cmol\ kg^{-1})$	14.30 ± 1.59	13.24 ± 1.34	13.32 ± 1.30	12.95 ± 1.33
S		10.57 ± 3.97	9.85 ± 2.87	9.10 ± 1.54	7.85 ± 0.85
CEC		24.87 ± 2.53	23.12 ± 1.67	22.42 ± 1.71	20.80 ± 1.43
V	(%)	41.33 ± 11.91	41.95 ± 9.81	40.48 ± 5.39	37.80 ± 3.74

TOC, total organic carbon; pH_{H2O}, active soil reaction; pH_{KCl}, exchange soil reaction; $N\text{-}NH_4^+$, ammonium nitrogen; $N\text{-}NO_3^-$, nitrate nitrogen; N_{in}, inorganic nitrogen; N_T, total nitrogen; HS, humic substance; HA, humic acid; FA, fulvic acid; H, hydrolytic acidity; S, basic cation; CEC, cation exchange capacity; V, base saturation.

Table 2b. Mown meadow – average values of soil chemical properties (mean value ± standard deviation)

Chemical properties		2011	2012		2013
		Autumn	Spring	Autumn	Spring
TOC	(%)	2.85 ± 1.59	4.65 ± 2.99	7.42 ± 6.01	5.15 ± 3.00
pH_{H2O}		5.77 ± 0.49	5.41 ± 0.10	5.75 ± 0.29	5.66 ± 0.21
pH_{KCl}		4.46 ± 0.22	4.48 ± 0.10	4.49 ± 0.19	4.48 ± 0.32
$N\text{-}NH_4^+$	$(mg\ kg^{-1})$	9.80 ± 7.25	52.88 ± 24.37	27.62 ± 6.09	42.35 ± 23.18
$N\text{-}NO_3^-$		4.92 ± 0.68	7.63 ± 1.79	8.37 ± 2.86	8.98 ± 1.80
N_{in}		14.72 ± 7.66	60.52 ± 25.65	35.98 ± 6.57	51.33 ± 24.06
N_T		3.25 ± 1.88	5.20 ± 3.70	11.73 ± 9.04	5.72 ± 2.80
HS	(%)	3.05 ± 0.90	3.12 ± 1.40	3.32 ± 1.23	2.38 ± 1.41
HA		1.15 ± 0.30	1.03 ± 0.35	1.24 ± 0.43	0.57 ± 0.36
FA		1.90 ± 0.65	2.90 ± 1.08	2.09 ± 0.85	1.81 ± 1.08
HA : FA		0.71 ± 0.37	0.77 ± 0.58	0.73 ± 0.35	0.63 ± 0.51
C : N		9.68 ± 1.91	9.72 ± 1.50	7.70 ± 3.12	8.94 ± 1.89
H	$(cmol\ kg^{-1})$	6.57 ± 1.83	5.27 ± 0.66	3.63 ± 0.64	4.09 ± 0.75
S		7.22 ± 1.61	5.92 ± 0.86	5.53 ± 1.48	4.83 ± 0.65
CEC		13.78 ± 3.39	11.18 ± 1.36	9.17 ± 1.96	8.92 ± 1.38
V	(%)	52.70 ± 2.92	52.81 ± 3.25	59.97 ± 4.05	54.31 ± 1.75

TOC, total organic carbon; pH_{H2O}, active soil reaction; pH_{KCl}, exchange soil reaction; $N\text{-}NH_4^+$, ammonium nitrogen; $N\text{-}NO_3^-$, nitrate nitrogen; N_{in}, inorganic nitrogen; N_T, total nitrogen; HS, humic substance; HA, humic acid; FA, fulvic acid; H, hydrolytic acidity; S, basic cation; CEC, cation exchange capacity; V, base saturation.

Table 2c. Xerothermic meadow – average values of soil chemical properties (mean value ± standard deviation)

Chemical properties		2011 Autumn	2012 Spring	2012 Autumn	2013 Spring
TOC	(%)	8.93 ± 4.94	5.27 ± 2.20	7.43 ± 3.86	4.14 ± 3.28
pH_{H2O}		5.26 ± 0.90	5.15 ± 0.36	5.70 ± 0.36	5.61 ± 0.40
pH_{KCl}		4.04 ± 0.33	3.96 ± 0.22	4.21 ± 0.32	4.47 ± 0.34
$N\text{-}NH_4^+$	(mg kg^{-1})	26.30 ± 21.64	69.80 ± 36.76	34.63 ± 16.64	51.10 ± 33.47
$N\text{-}NO_3^-$		6.83 ± 4.50	5.65 ± 1.34	7.48 ± 1.27	7.17 ± 2.10
N_{in}		33.13 ± 24.83	75.45 ± 37.79	42.11 ± 17.43	58.27 ± 35.44
N_T		16.54 ± 8.90	9.03 ± 3.08	13.13 ± 5.54	5.80 ± 4.70
HS	(%)	4.50 ± 2.27	4.62 ± 1.63	4.21 ± 3.03	3.01 ± 2.30
HA		0.82 ± 0.53	1.45 ± 0.34	0.82 ± 0.53	0.80 ± 0.67
FA		3.68 ± 1.88	3.17 ± 1.30	3,39 ± 3.33	2.21 ± 1.64
HA : FA		0.31 ± 0.23	0.50 ± 0.10	0.59 ± 0.37	0.76 ± 0.51
C : N		5.22 ± 0.67	5.72 ± 0.54	5.52 ± 0.79	8.84 ± 3.03
H	(cmol kg^{-1})	5.10 ± 0.89	3.80 ± 0.54	3.55 ± 1.17	3.77 ± 0.99
S		7.25 ± 1.42	5.28 ± 0.84	4.68 ± 1.13	4.98 ± 1.21
CEC		12.35 ± 2.19	9.08 ± 1.36	8.23 ± 2.23	8.74 ± 2.12
V	(%)	59.50 ± 2.92	58.08 ± 1.44	57.48 ± 4.05	57.20 ± 3.92

TOC, total organic carbon; pH_{H2O}, active soil reaction; pH_{KCl}, exchange soil reaction; $N\text{-}NH_4^+$, ammonium nitrogen; $N\text{-}NO_3^-$, nitrate nitrogen; N_{in}, inorganic nitrogen; N_T, total nitrogen; HS, humic substance; HA, humic acid; FA, fulvic acid; H, hydrolytic acidity; S, basic cation; CEC, cation exchange capacity; V, base saturation.

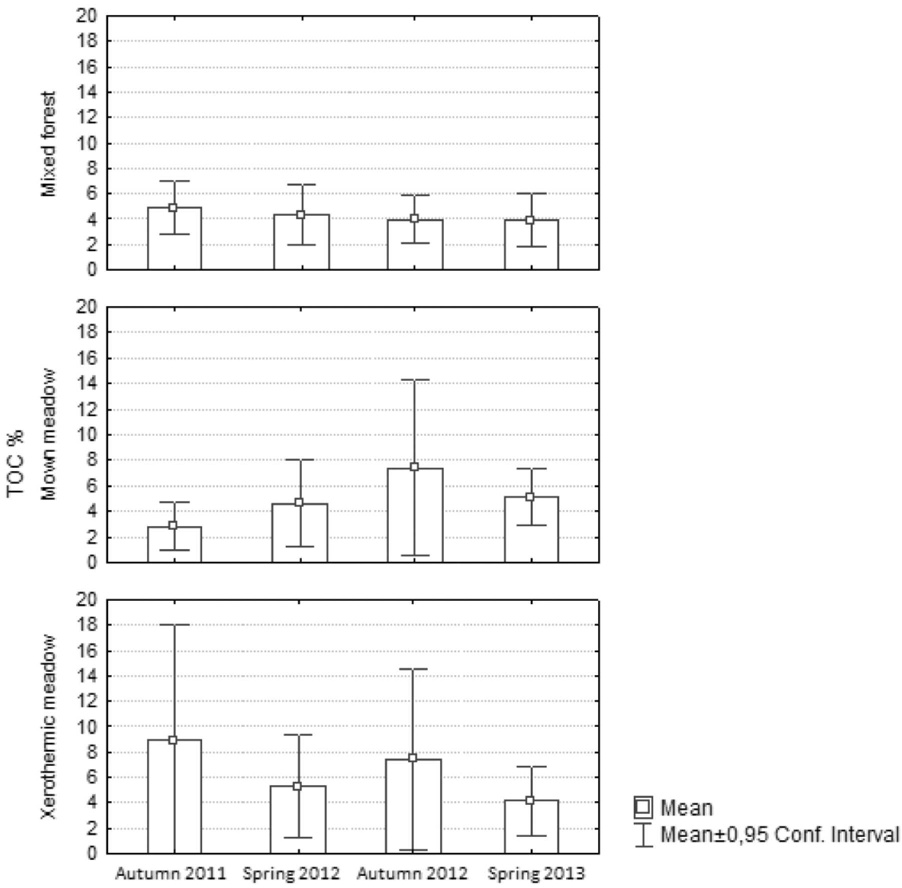

Fig. 2. Variability of TOC (total organic carbon) depending on the land use in different years.

and ZASADA, 2014). The highest variability in terms of values between seasons was detected in the case of xerothermic meadows (Table 3), probably because of the fresh organic substance supply during the whole year.

Land use had a statistically significant impact on difference in active values ($F = 7.5001$, $p = 0.001$) and exchange soil reaction ($F = 18.8866$, $p = 0.000$) (Table 4). According to ISLAM and WEIL (2000), the pH values of the natural forest, reforested land, grassland and cultivated soils, varied significantly. A drop in pH values was also indicative of the process of soil transformation (KALISZ et al., 2010). GÜNDOĞAN et al. (2011) detected statistically significant differences in the values of active soil reaction between grassland, forest and arable land, while grassland had significantly higher pH than both forest and arable lands ($p < 0.05$). The drop in soil acidity and the nitrogen deposition in the context of contemporary climate change will limit the silvicultural function of forest communities (JANÍK et al., 2014). The soils of xerothermic and mown meadows on the neovolcanic rocks of central Slovakia were significantly more acidic than that of the mixed forest ($p < 0.05$), probably because of the highest average TOC content in the soil, and eventually because of the high content of basic cations in the soil of the mixed forest.

The content of ammonia nitrogen ($N\text{-}NH_4^+$), originating during the biological decomposition of organic samples in soil, was influenced not only by different types of ecosystem, but also by the season ($F = 13.2885$, $p = 0.001$) (Table 4).

Total nitrogen (N_T) was affected by the land use and decreased from xerothermic meadows to the mixed forests ($p < 0.001$) following a pattern similar to that shown by TOC ($F = 11.7573$, $p = 0.000$). Soil organic C and N have been proposed as useful indicators of soil quality (ARSHAD and COEN, 1992). A statistically significant difference in the values of N_T was also detected between individual seasons ($p < 0.01$) ($F = 8.0201$, $p = 0.006$). This was probably associated with a different rate of mineralization of the plant material fallout, and the intensity of nutrient uptake by plants (BIELIŃSKA et al., 2008). Mutual interaction of factors of the land use and seasonal differences also affect the content of N_T ($Z = 3.5117$, $p = 0.035$). ISLAM and WEIL (2000) did not detect any statistically significant difference in N_T content between ecosystems (natural forest, reforested land, grassland, cultivated land). The impact between total C and N depends on the type of ecosystem ($F = 46.753$, $p = 0.000$) on the importance level $\alpha = 0.001$, which does not correlate with the ISLAM and WEIL (2000) results, but partially correlates with the results of WRÓBEL et al. (2012). A positive correlation was found between the total nitrogen and inorganic nitrogen content but this was not statistically significant ($r = 0.428$). In the soil of mixed forests, we found a positive correlation between total nitrogen and inorganic nitrogen ($r = 0.618$) at a significance level of $\alpha = 0.05$. A correlation between total and inorganic nitrogen in the soil of the mown meadow ($r = 0.274$, $p = 0.158$) and the xerothermic meadow ($r = 0.311$, $p = 0.170$) was not found. Using the variance analysis, we found statistically significant differences in the content of inorganic nitrogen for different ecosystems ($F = 7.3197$, $p = 0.0013$) (Table 4).

Table 3. Mineral fraction composition of the studied andosols soil types

Structure		Sand (%)	Clay (%)	Silt (%)
Mixed forest				
2011	Autumn	45.83 ± 7.21	19.59 ± 4.97	34.48 ± 7.99
2012	Spring	45.83 ± 3.03	18.90 ± 2.83	35.27 ± 2.65
	Autumn	50.13 ± 4.65	17.98 ± 3.29	31.88 ± 7.40
2013	Spring	48.73 ± 3.17	13.77 ± 4.00	37.50 ± 5.84
Mown meadow				
2011	Autumn	39.22 ± 8.43	30.85 ± 3.77	29.93 ± 8.66
2012	Spring	36.72 ± 8.47	32.97 ± 6.45	30.30 ± 6.87
	Autumn	38.07 ± 9.17	33.57 ± 4.96	28.37 ± 11.17
2013	Spring	27.40 ± 5.88	33.75 ± 8.61	38.85 ± 7.28
Xerothermic meadow				
2011	Autumn	44.30 ± 6.08	13.13 ± 3.14	42.58 ± 4.45
2012	Spring	39.23 ± 5.93	10.40 ± 6.13	50.38 ± 1.54
	Autumn	44.63 ± 7.49	15.98 ± 7.37	39.40 ± 3.23
2013	Spring	34.56 ± 11.85	27.66 ± 18.45	40.96 ± 19.30

Sand – mineral particles of ø 2,000–50 μm; Clay – mineral particles of Ø < 2 μm; Silt – mineral particles of ø 50–2 μm.

Table 4. Variance analysis of soil chemical characteristics depending on the land use and season with the mutual interaction

	Effect	Test statistics	Significant level
TOC	Seasons	2.8697	0.094904
	Ecosystem	1.9329	0.152717
	Seasons-Ecosystem	1.7632	0.179355
pH_{H2O}	Seasons	0.5990	0.441695
	Ecosystem	7.5001	0.001150**
	Seasons-Ecosystem	0.3258	0.723118
pH_{KCl}	Seasons	3.4283	0.068496
	Ecosystem	18.8866	0.000000***
	Seasons-Ecosystem	0.8907	0.415154
$N\text{-}NH_4^+$	Seasons	13.2885	0.000522***
	Ecosystem	9.3602	0.000260***
	Seasons-Ecosystem	2.6964	0.074767
$N\text{-}NO_3^-$	Seasons	1.5472	0.217884
	Ecosystem	3.1105	0.051075
	Seasons-Ecosystem	1.2948	0.280725
N_{in}	Seasons	12.8053	0.000648***
	Ecosystem	7.3197	0.001333**
	Seasons-Ecosystem	2.4611	0.093025
N_T	Seasons	8.0201	0.006103**
	Ecosystem	1.7573	0.000042***
	Seasons-Ecosystem	3.5117	0.035454*
HS	Seasons	2.5397	0.115723
	Ecosystem	2.5041	0.089374
	Seasons-Ecosystem	0.0620	0.939957
HA	Seasons	2.4587	0.121585
	Ecosystem	16.7532	0.000001***
	Seasons-Ecosystem	2.3766	0.100650
FA	Seasons	1.9624	0.165871
	Ecosystem	3.9019	0.024949*
	Seasons-Ecosystem	0.7402	0.480893
H	Seasons	3.1800	0.079093
	Ecosystem	318.4540	0.000000***
	Seasons-Ecosystem	0.0200	0.980594
S	Seasons	4.3164	0.041582*
	Ecosystem	26.1312	0.000000***
	Seasons-Ecosystem	0.0223	0.977990
CEC	Seasons	6.8150	0.011145*
	Ecosystem	191.3430	0.000000***
	Seasons-Ecosystem	0.0170	0.982678
V	Seasons	0.9270	0.339140
	Ecosystem	56.4080	0.000000***
	Seasons-Ecosystem	0.1990	0.819754
Sand	Seasons	6.6883	0.011884*
	Ecosystem	2.8143	0.067049
	Seasons-Ecosystem	2.8211	0.066629

Table 4. Variance analysis of soil chemical characteristics depending on the land use and season with the mutual interaction – continued

	Effect	Test statistics	Significant level
Clay	Seasons	2.7144	0.104129
	Ecosystem	1.1524	0.322073
	Seasons-Ecosystem	1.1436	0.324798
Silt	Seasons	3.0175	0.086967
	Ecosystem	2.7779	0.069340
	Seasons-Ecosystem	2.7664	0.070084
Texture	Seasons	1.6000	0.212172
	Ecosystem	12.5000	0.000025***
	Seasons-Ecosystem	3.7000	0.029227*

Significant differences at ***p < 0.001, **p < 0.01, *p < 0.05.
TOC, total organic carbon; pH_{H2O}, active soil reaction; pH_{KCl}, exchange soil reaction; N-NH_4^+, ammonium nitrogen; N-NO_3^-, nitrate nitrogen; N_{in}, inorganic nitrogen; N_T, total nitrogen; HS, humic substance; HA, humic acid; FA, fulvic acid; H, hydrolytic acidity; S, basic cation; CEC, cation exchange capacity; V, base saturation.

The mineralization of organic carbon compounds was also demonstrated by the C : N ratio (Kalisz et al., 2010; Małecka and Hilszczańska, 2014). The C : N ratio dropped from about 13 : 15 in the mixed forest to below 8 : 10 in the mown meadow and 5 : 9 in the xerothermic meadow (Table 2). The C : N ratio showed a negative correlation with the inorganic nitrogen (r = –0.321) for all types of landscape with a significance level of α = 0.05. Soils with a lower C : N ratio have a greater potential to decompose organic material and to release plant nutrients (N, P, K, etc.) into the soil environment (Koçyigit and Rice, 2004). Mineralization is a primarily biological process that converts organic N in decomposing litter to inorganic N in the form of NH_4^+ (Paul and Clark, 1996). It can provide up to 75% of the mineral N input in forest soil (Berendse et al., 1989). As for decomposition in general, pH, moisture, temperature, and in particular, soil C and N concentrations, and the C : N ratio of the litter material, seem to have the strongest influence on the mineralization rates (Andersson et al., 2002; Booth et al., 2005). When decomposing substrates with a high C : N ratio, microorganisms will retain more inorganic N (mainly as NH_4^+) during decomposition, thus reducing the availability of this N pool to plants. Conversely, if the C : N ratio of the substrate is lower than that of the decomposers, microorganisms will increase the size of the mineralized N pool in the soil (Belyazid et al., 2013).

Even though that difference in TOC content is not impacted by land use, there is a statistically significant difference between individual humic fractions, in terms of humic acid (HA) (F = 16.7532, p = 0.000) and fulvic acid (FA) (F = 3.9019, p = 0.025). The connection between HA : FA was not detected as being influenced by land use (F = 1.0016, p = 0.372). Connexion of HA : FA in andosols represented values averaging 0.700. In Kobza's (2008) opinion with regard to andosols, there is a high humic content and, despite its quality, there is a relatively low HA : FA < 1. However, little information is available on the impact of different methods of application in terms of HS on nutrient status, especially in the soil and climate conditions of the temperate zone (Osvalde et al., 2012).

The soil of a forest ecosystem (mixed forest) has been based on the detected values (cations exchangeable capacity and the sum of basic cations) to the soil with the highest sorption capacity (Tables 2a–c). Variability in terms of the values of CEC and S between a forest ecosystem (mixed forest) and a meadow ecosystem (mown and xerothermic meadows) was statistically significant (Table 4). Hydrolytic acidity was positively correlated to humic substances (humic acid and fulvic acid) in the forest ecosystem.

The sand (36.28 %) and silt (40.07 %) are dominant in the case of grain size of the andosol soil (Table 3). According to Kobza (2008), the fraction 0.002–0.05 mm (silt) and 0.05–2 mm (sand) dominates in the whole soil profile. According to Covaleda et al. (2011) the determination of particle-size fractions is useful in studying the effect of land use change on soil carbon stocks, but few studies have been carried out to determine the effect of forest cover depletion on particle-size fractions, and even less so in volcanic soils. Based on our results, land use did not have a statistically significant influence on grain soil structure, which does not agree with the argument of Agoume and Birang (2009), who state that land-use systems significantly affect the clay, silt and sand fractions. The organic matter content of the soil is in positive correlation with the clay fraction (Bosatta and Agren, 1997). In our case, TOC was negatively correlated to sand fraction in the soil of the mixed forest ($r = –0.408$, $p < 0.05$), and in soil of the xerothermic meadow. Within all observed and examined ecosystems, we detected a negative correlation between TOC and clay fraction ($r = –0.230$, $p < 0.05$). Tobiašová et al. (2012) and Pan et al. (2013) detected a negative correlation between TOC and sand fraction, and a positive correlation between silt and clay fractions. The TOC of grassland (mown and xerothermic meadows) was positively correlated with N_T ($r = 0.960$, $p < 0.05$), which is comparable to the argument of Pan et al. (2013). In the case of mown meadows, with the help of correlation analysis between the

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

	Ecosystems	pH_{H2O}	pH_{KCl}	H	S	CEC	V	Sand	Clay	Silt	Texture
TOC	MF	0.305	0.567*	0.379	–	–	–	–	–0.015	0.327	–0.178
	MM	–	0.222	–0.067	0.170	0.331	0.269	–0.025	–0.257	0.318	0.153
	XM	–	–	0.296	0.225	0.263	–0.235	–	–0.314	–0.213	–0.154
HS	MF	0.138	0.162	0.529*	–0.331	–0.058	–	–	–0.124	0.401	–0.323
	MM	–	0.083	0.224	0.265	0.255	–0.033	–0.228	–	–0.009	0.191
	XM	–	–	–0.046	–0.037	–0.042	–0.035	–	–0.344	–0.335	–0.181
HA	MF	0.145	0.072	0.568*	–0.374	–0.084	–	–0.357	–0.194	0.407*	–0.299
	MM	–0.206	0.008	0.345	0.483*	0.432*	0.066	–0.367	–	–0.111	0.193
	XM	–	–	0.170	0.035	0.095	–0.385	–	–0.323	–0.360	–0.133
FA	MF	0.126	0.224	0.474*	–0.282	–0.035	–	–	–0.065	0.377	–0.326
	MM	–	0.111	0.146	0.137	0.148	–0.076	–0.140	–	0.040	0.172
	XM	–0.401	–	–0.101	–0.052	–0.075	0.071	–0.431	–0.299	–0.278	–0.168
$N\text{-}NH_4^+$	MF	0.556*	0.721*	0.147	–	–	–0.366	–0.332	0.162	0.153	–0.264
	MM	–0.364	0.211	–0.065	–0.145	–0.109	–0.146	0.230	–0.205	0.140	0.031
	XM	–	–0.252	0.162	0.066	0.109	–0.272	–0.333	–0.233	0.133	0.223
$N\text{-}NO_3^-$	MF	0.384	0.582*	–0.001	–0.367	–	–0.276	–	0.046	0.288	–0.199
	MM	0.000	–0.146	–0.366	–0.325	–0.362	0.216	0.332	0.063	0.068	0.055
	XM	–0.322	–0.298	–0.056	–0.165	–0.123	–0.244	–0.220	–0.170	0.046	0.160
N_{in}	MF	0.541*	0.730*	0.107	–	–	–0.364	–0.385	0.134	0.212	–0.262
	MM	–0.344	0.185	–0.097	–0.169	–0.138	–0.117	0.250	–0.188	0.139	0.035
	XM	–	–0.264	0.151	0.050	0.096	–0.280	–0.336	–0.237	0.131	0.226
N_T	MF	0.288	0.559*	0.374	–	–0.403	–	–	0.002	0.315	–0.175
	MM	–0.333	0.227	–0.151	0.114	–0.022	0.347	–0.102	–0.209	0.303	0.149
	XM	–	–	0.250	0.203	0.230	–0.185	–	–0.309	–0.317	–0.241
HA:FA	MF	0.085	–0.327	0.150	–0.105	–0.030	–0.142	0.222	–0.237	–0.012	0.098
	MM	0.530*	0.204	–0.050	0.014	–0.019	0.110	0.149	0.283	0.088	–0.132
	XM	0.417	0.317	–	–0.385	–0.434	0.306	0.917*	0.563*	–0.222	–0.230
C : N	MF	–0.256	–	–0.397	0.446*	0.275	0.487*	0.321	–0.030	–0.227	0.097
	MM	0.443*	0.112	0.155	0.094	0.131	–0.127	0.047	–0.020	–0.225	–0.062
	XM	0.303	0.532*	–0.366	–0.238	–0.301	0.369	0.845*	0.558*	0.294	0.241

Significant differences at $*p < 0.05$.
MF, mixed forest; MM, mown meadow; XM, xerothermic meadow; TOC, total organic carbon; pH_{H2O}, active soil reaction; pH_{KCl}, exchange soil reaction; $N\text{-}NH_4^+$, ammonium nitrogen; $N\text{-}NO_3^-$, nitrate nitrogen; N_{in}, inorganic nitrogen; N_T, total nitrogen; HS, humic substance; HA, humic acid; FA, fulvic acid; H, hydrolytic acidity; S, basic cation; CEC, cation exchange capacity; V, base saturation.

parameters of carbon and nitrogen and the parameters of sorption complex, soil reaction and fractions on the different ecosystems, we detected a negative influence of the clay fraction on the content of humic substances (Table 5). The clay fraction was negatively correlated with humic acids ($r = –0.550$, $p < 0.05$) and also with fulvic acids ($r = –0.440$, $p < 0.05$).

Conclusions

The highest average TOC and basic cations content were in the soil of the mixed forest. The xerothermic and mown meadows were more acidic ($p < 0.05$) than the soil of the mixed forest. In our case, the land use did not influence the TOC values ($F = 1.933$, $p = 0.153$). Humic substances are typical products of humifical transformations. The process of humification is contingent on a whole line of environmental and ecological factors. Locality, soil type, slope relief, season, climate, altitude and also the use of ground cover have a huge impact on the whole process. Statistically significant differences between the monitored ecosystems were found in terms of the humic acid ($F = 16.753$, $p = 0.000$) and the fulvic acid content ($F = 3.9019$, $p = 0.025$). One of the reasons for the creation of humic substances are different herbal and zoological remainders entering the humification process. Humic acids are present in all herbs, soils and animals, and they are a natural part of the food chain, and undertake unchangeable tasks during the transformation of lifeless substances into nutriments. In the mixed forest soil we determined the minimal differences in the TOC content during the monitoring period 2011–2013 (spring, autumn). This is thanks to the regular supply of organic matter in the forest soil from the root system and logging residues.

In the soil of the mixed forest, we found a positive correlation between total nitrogen and inorganic nitrogen ($r = 0.618$) at a significance level of $\alpha = 0.05$. A significant correlation between total and inorganic nitrogen in the soil of the mown meadow ($r = 0.274$, $p = 0.158$) and the xerothermic meadow ($r = 0.311$, $p = 0.170$) was not found. The most important transformations of nitrogen in soil relate to the biological N fixation, which positively affects the forest ecosystem. Nitrogen is bound directly into the soil through the roots.

The forest ecosystem has an important role in the carbon cycle through the transformation of inorganic carbon to organic carbon as well as in the process of accumulation that consists of sequestration, humification and decomposition, which lead to the formation of carbon stocks in the deeper layers of the soil.

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References

Agoume, V., Birang, A.M., 2009. Impact of land-use systems on some physical and chemical soil properties of an oxisol in the humid forest zone of Southern Cameroon. *Tropicultura,* 27: 15–20.

Aleksandrowicz-Trzcińska, M., 2005. Stan mikoryz sosny zwyczajnej w uprawie założonej na gruncie porolnym [Mycorrhizae condition of Scots pine in cultivation founded on the basis porolnym]. *Sylwan,* 149: 42–49.

Andersson, P., Berggren, D., Nilsson, I., 2002. Indices for nitrogen status and nitrate leaching from Norway spruce (Picea abies (L.) Karst.) stands in Sweden. *Forest Ecology and Management,* 157: 39–53.

Armas-Herrera, C.M., Mora, J.L., Arbelo, C.D., Rodríguez-Rodríguez, A., 2012. Interannual variations of soil organic carbon fractions in unmanaged volcanic soils (Canary Islands, Spain). *Ecology and Evolution,* 2: 2374–2386.

Arrouays, D., Deslais, W., Badeau, V., 2001**.** The carbon content of top soil and its geographical distribution in France. *Soil Use and Management,* 17: 7–11.

Arshad, M.A., Coen, G.M., 1992. Characterization of soil quality: Physical and chemical criteria. *American Journal of Alternative Agriculture*, 7: 25–31.

Balkovič, J. 2002. *Soils with andic properties in chosen Slovakian mountains*. PhD thesis. Bratislava: Comenius University in Bratislava, Slovakia. 144 p.

Belyazid, U.J., Belyazid, S., Akselsson, C., 2013. *Nitrogen in boreal forest ecosystems – The influence of climate change, nitrogen fertilization, whole-tree harvest and stump harvest on the nitrogen cycle. A report from Belyazid Consulting & Communication*. Appendix to the report Effects of climate change, nitrogen fertilization, whole-tree harvesting and stump harvesting on boreal forest ecosystems – A review of current knowledge and evaluation of how these factors may influence the possibilities to reach the Swedish environmental objectives. 48 p. [cit. 2015-06-30]. http://belyazid.com/doks/Nitrogencycling.pdf

Berendse, F., Bobbink, R., Rouwenhorst, G., 1989. A comparative study on nutrient cycling in wet heathland ecosystems. II. Litter decomposition and nutrient mineralization. *Oecologia*, 78: 338–348.

Bielińska, E.J., Mocek-Płóciniak, A., Kaczmarek, Z., 2008. Eco-chemical forest soil indices from a forest fire. *Polish Journal of Environmental Studies*, 17: 665–671.

Bierkens, M.F.P., Dolman, A.J., Troch, P.A., 2008. *Climate and the hydrological cycle*. IAHS special publications 8. Wallingford, UK: IAHS Press. 344 p.

Booth, M.S., Stark, J.M., Rastetter, E., 2005. Controls on nitrogen cycling in terrestrial ecosystems: A synthetic analysis of literature data. *Ecological Monographs*, 75: 139–157.

Bosatta, E., Ågren, G.I., 1997. Theoretical analyses of soil texture effects on organic matter dynamics. *Soil Biology and Biochemistry,* 29: 1633–1638.

Braun-Blanquet, J., 1964. *Pflanzensoziologie. Grundzüge der Vegetationskunde*. Wien; New York: Springer-Verlag. 866 p.

Bremner, J.M., 1960. Determination of nitrogen in soil by Kjeldahl method. *Journal of Agricultural Science,* 55: 1–23.

Bronick, C.J., Lal, R., 2005. Soil structure and management: a review. *Geoderma,* 124 (1–2): 3–22.

Covaleda, S., Gallardo, J.F., García., Oliva, F., Kirchmann, H., Prat, C., Bravo, M., Etchevers, J.D., 2011. Land-use effects on the distribution of soil organic carbon within particle-size fractions of volcanic soils in the Transmexican Volcanic Belt (Mexico). *Soil Use and Management,* 27: 186–194.

Galka, B. , Labaz, B., Bogacz, A., Bojko, O., Kabala, C., 2014. Conversion of Norway spruce forests will reduce organic carbon pools in the mountain soils of SW Poland. *Geoderma*, 213: 287–295.

Gärdenäs, A.I., Ågren, G.I., Bird, J.A., Clarholm, M., Hallin, S., Ineson, P., Kätterer, T., Knicker, H., Nilsson, S.I., Näsholm, T., Ogle, S., Pustian, K., Persson, T., Stendhahl, J., 2011. Knowledge gaps in soil carbon and nitrogen interactions – from molecular to global scale. *Soil Biology and Biochemistry*, 43: 702–717.

Gömöry, D., Paule, L., Longauer, R., 2015. Geografické trendy genetickej premenlivosti lesných drevín v Karpatoch [Geographic trends of genetic variety of forest trees in Carpathian Mountains]. In Lukáčik. I., Sarvašová, I. (eds). *Dendroflóra strednej Európy – využitie poznatkov vo výskume, vzdelávaní a praxi.* Zvolen: Technická univerzita vo Zvolene, 2015, p. 19–29.

Gündoğan, R., Özyurt, H., Akay, A.E., 2011. The effects of land use on properties of soils developed over ophiolites in Turkey. *International Journal of Forest, Soil and Erosion,* 1: 36–42.

Hill, M.O., 1979. *TWINSPAN. A Fortran program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes*. Ithaca: Cornell University. 90 p.

Hennekens, S.M., Schaminée, J.H.J., 2001. Turboveg, a comprehensive data base management system for vegetation data. *Journal of Vegetation Science*, 12: 589–591.

Hudec, M., Hreško, J., 2012. Obsah humusu na pôdach kamenných miest Kremnických vrchov [The content of humus on rocky soils Kremnické vrchy Mts]. *Ekologické štúdie,* 3 (2): 20–27.

Islam, K.R., Weil, R.R., 2000. Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. *Agriculture, Ecosystems and Environment,* 79: 9–16.

IUSS Working Group WRB, 2006. *World reference base for soil resources*. 2nd ed. World soil resources report, no. 103. Rome: FAO. 132 p.

Jackson, M.L., 2005. *Soil chemical analysis. Advanced course. A manual of methods useful for instruction and research in soil chemistry, physical chemistry of soil, soil fertility and soil genesis.* Madison: University of Wisconsin – Madison Libraries. 930 p.

Jagodziński, A., Oleksyn, J., 2009a. Ekologiczne konsekwencje hodowli drzew w różnym zagęszczeniu. I. Wzrost i rozwój drzewostanu [Ecological consequences of breeding trees in varying densities I. Growth and development of the stand]. *Sylwan,* 153: 75–85.

Jagodziński, A., Oleksyn, J., 2009b. Ekologiczne konsekwencje hodowli drzew w różnym zagęszczeniu. II. Produkcja i alokacja biomasy, retencja biogenów [Ecological consequences of silviculture at variable stand densities. II. Biomass production and allocation, nutrient retention]. *Sylwan,* 153: 147–157.

Janík, R., Bublinec, E., Dubová, M., 2014. Space-time patterns of soil pH and conductivity in submountain beech ecosystems in the West Carpathians. *Folia Oecologica,* 41: 141–145.

Janišová, M., Hájková, P., Hegedüšová, K., Hrivnák, R., Kliment, J., Michálková, D., Ružičková, H., Řezníčková, M., Tichý, L., Škodová, I., Uhliarová, E., Ujházy, K., Zaliberová, M., 2007. *Travinno-bylinná vegetácia Slovenska – elektronický expertný systém na identifikáciu syntaxónov* [Grassland vegetation of Slovak Republic – electronic expert system for identification of syntaxa]. Bratislava: Botanický ústav SAV. 263 p.

Jarolímek, I., Šibík, J., Hegedüšová, K., Janišová, M., Kliment, J., Kučera, P., Májeková, K., Michálková, D., Sadloňová, J., Šibíková, J., Škodová, I., Uhlířová, J., Ujházy, K., Ujházyová, M., Valachovič, M., Zaliberová, M., 2008. A list of vegetation units of Slovakia. In Jarolímek, I., Šibík, J. (eds). *Diagnostic, constant and dominant species of the higher vegetation units of Slovakia*. Bratislava: Veda, p. 295–329.

Juráni, B., Balkovič, J., 2007. *Soil of volcanic regions in Slovakia. Soils of volcanic regions in Europe*. Berlin: Springer, p. 82–102.

Jurgensen, M.F., Harvey, A.E., Graham, R.T., Page-Dumroese, D.S., Tonn, J. R., Larsen, M.J, Jain, T.B., 1997. Impacts of timber harvesting on soil organic matter, nitrogen, productivity, and health of Inland Northwest Forests. *Forest Science,* 43 (2): 234–251.

Kalisz, B., Lachacz, B., Glazewski, R., 2010. Transformation of some organic matter components in organic soils exposed to drainage. *Turkish Journal of Agriculture and Forestry,* 34: 245–256.

Kobza, J., 2008. Poznámky ku genéze andozemných pôd a problém ich klasifikácie [Notes to genesis of andosols and the problems of their classification]. In *Vedecké práce Výskumného ústavu pôdoznalectva a ochrany pôdy č. 30*. Bratislava: Výskumý ústav pôdoznalectva a ochrany pôdy, p. 55–61.

Koçyigit, R., Rice, Ch.W., 2004. Carbon dynamics in tallgrass prairie and wheat ecosystems. *Turkish Journal of Agriculture and Forestry,* 28: 141–153.

Kononova, M.M., 1966. *Soil organic matter. Its nature, its role in soil formation and in soil fertility*. London: Pergamon Press. 544 p.

Kononova, M.M., Belčikova, N.P., 1962. Uskorennyje metody opredelenija sostava gumusa mineralnych počv [Simplified methods of humus determination in mineral soils]. *Počvovedenije*, 10: 75–87.

Kwaśna, H., Brzeski, M.W., Sierota, Z., 2001. Mikroorganizmy środowiska glebowego odłogujących gruntów porolnych – zmiany w zbiorowiskach grzybów i nicieni po dodaniu trocin iglastych [Microorganisms of soil environment fallow former farmland – changes in the communities of fungi and nematodes after adding sawdust conifers]. In Dahm, H., Pokojska, A. (red.). *Drobnoustroje środowiska glebowego – aspekty fizjologiczne, biochemiczne, genetyczne.* Toruń: Wyd. A. Marszałek, p. 57–66.

Kwaśna, H., Sierota, Z., Bateman, G.L., 2000**.** Fungal communities in fallow soil before and after amending with pine sawdust. *Applied Soil Ecology*, 14: 177–182.

Lal, R., 2000. Soil management in developing countries. *Soil Science,* 165: 57–72.

Liu, X.L., He, Y. Q., Zhang, H.L., Schroder, J.K., Li, C.L., Zhou, J., Zhang, Z.Y., 2010. Impact of land use and soil fertility on distributions of soil aggregate fractions and some nutrients. *Pedosphere*, 20: 666–673.

Małecka, M., Hilszczańska, D., 2014. Changes in ectomycorrhizal structure of Scots pine growing on abandoned farmland soil enriched with organic substrates. *Sylwan,* 158: 243−250.

Marhold, K., Hindák, F., 1998. *Zoznam nižších a vyšších rastlín Slovenska* [Checklist of non-vascular and vascular plants of Slovakia]. Bratislava: Veda. 687 p.

Martellotto, A., 2010. *The impact of long-term tillage, crop rotation and N application on soil carbon sequestration.* Theses, dissertations and student research in agronomy and horticulture. Lincoln: University of Nebraska. [94 p.] [cit. 2015-05-30]. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1022&context=agronhortdiss

Mora, J.L., Guerra, J.A., Armas-Herrera, C.M., Arbelo, C.D., Rodríguez- Rodríguez, A., 2014. Storage and depth distribution of organic carbon in volcanic soils as affected by environmental and pedological factors. *Catena,* 123: 163–175.

Mutsotso, B., Muya, E.M., 2008. Characteristics of below-ground biodiversity sites in Kenya: Their constrants, interventions and emerging issues. *Tropical and Subtropical Agroecosystems: An International Multidisciplinary Journal*, p. 991–1003.

Navarrete, I.A., Tsutsuki, K., Navarrete, R.A., 2010. Humus composition and the structural characteristics of humic substances in soils under different land use in Leyte, Philippines. *Soil Science and Plant Nutrition,* 56: 289–296.

Neris, J., Jiménez, C., Fuentes, G., Morillas, G., Tejedor, M., 2012. Vegetation and land-use effects on soil properties and water infiltration of Andisols in Tenerife (Canary Islands, Spain). *Catena,* 98: 55–62.

Novák, P., Khel, T., Vopravil, J., Lagov, J., 2010. Do andosols occur in the Czech Republic? *Soil and Water Research,* 5: 161–171.

Nozdrovický, L., Rataj, V., Galambošová, J., Kollárová, K., Macák, M., Halva, J., Tuček, J., Koreň, M., Smreček, R., 2008. *Presné pôdohospodárstvo: implementácia s podporou informačných technológií a techniky* [The precision agriculture: the implementation of information technology support and technology]. Nitra: Slovenská poľnohospodárska univerzita. 168 p.

Orlov, D., Grišina, L.A., 1981. *Praktikum po chemiji gumusa* [Chemical book of exercises for humus analyzing]. Moscow: Izdateľstvo Moskovskovo universiteta. 124 p.

Ostrowska, A., Porębska, G., 2012. Assessment of TOC-SOM and SOM-TOC conversion in forest soil. *Polish Journal of Environmental Studies,* 21: 1767–1775.

Osvalde, A., Karlsons, A., Čekstere, G., Maļecka, S., 2012. Effect of humic substances on nutrient status and yield of onion (Allium cepa L*.)* in field conditions. *Proceedings of the Latvian Academy of Scienc*es, 66 (4/5): 192–199.

Pach, M., Bartkowicz, L., Skoczeń, W., 2001. Charakterystyka cech biomorfologicznych świerka w borze górnore glowym Pilska w zależności od budowy i struktury drzewostanów [Characteristics of bio-morphological features of spruce in high mountain spruce forest in the Pilsko depending on the structure of the forest stands]. *Sylwan,* 145: 23–37.

Pan, Ch., Zhao, H., Zhao, X., Han, H., Wang, Y., Li, J., 2013. Biophysical properties as determinants for soil organic carbon and total nitrogen in grassland salinization. *PLoS One,* 8 (1): e54827.

Paul, E. A., Clark, F.E., 1996. *Soil microbiology and biochemistry*. 2nd ed. San Diego, USA: Academic Press. 340 p.

Radov, A.C., Pustov, I.V., Koroľkov, A.V., 1985. *Praktikum po agrochimiji* [Agro-chemical book of exercises]. Moskva: Agropromizdat.

Ryan, J., 1998. Changes in organic carbon in long-term rotation and tillage trials in northern Syria. In Lal, R., Kimble J.M., Follet, J.M., Stewart, R.F. (eds). *Management of carbon sequestration in soil.* Advances in soil science. New York: CRC Press, p. 285–-296.

Ryan, J., Masri, S., Ibrikçi, H., Singh, M., Pala, M., Harris, H.C., 2008. Implications of cereal-based crop rotations, nitrogen fertilization, and stubble grazing on soil organic matter in a Mediterranean-type environment. *Turkish Journal of Agriculture and Forestry,* 32: 289–297.

Sakbaeva, Z., Acosta-Martínez, V., Moore-Kucera, J., Hudnall, W., Nuridin, K., 2012. Interactions of soil order and land use management on soil properties in the Kukart watershed, Kyrgyzstan. *Applied and Environmental Soil Science,* 12: Article ID 130941.

Šlepetienė, A., Šlepetys J., Liaudanskienė I., 2010. Chemical composition of differently used Terric Histosols. *Zemdirbystė-Agriculture,* 97 (2): 25–32.

Socha, J., Zasada, M., 2014. Zagęszczenie i dynamika procesu wydzielania drzew w młodocianych drzewostanach brzozowych na gruntach porolnych [Stand density and self-thinning dynamics in young birch stands on post-agricultural land]. *Sylwan,* 158: 340–351.

Tichý, L., 2002. Juice, software for vegetation classification. *Journal of Vegetation Science*, 13: 451–453.

Tobiášová, E., Debska, B., Banach-Szott, M., 2012. Influence of particle size distribution of soil on quantity and quality of soil organic matter. *Acta Fytotechnica et Zootechnica,* 1: 13–18.

van der Maarel, E., 1979 Transformation of cover-abundance values in phytosociology and its effects on community similarity. *Vegetatio,* 39: 97–114.

van Reeuwijk, L.P., 2002. (ed.). *Producers for soil analysis*. Technical Paper (International Soil Reference and Information Centre), no. 9. Wageningen: International Soil Reference and Information Centre [cit. 2015-06-12]. http://www.isric.org/isric/webdocs/docs/ISRIC_TechPap09_2002.pdf

Wróbel, M., Gregorczyk, A., Wróbel, J., 2012. The effect of chemical soil properties on weed infestation structure in willow (Salix L.) short-rotation coppice. *Polish Jounal of Environmental Studies,* 21: 1893–1899.

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