PARTICLE-SIZE DISTRIBUTION AND LAND-USE EFFECTS ON QUANTITY AND QUALITY OF SOIL ORGANIC MATTER IN SELECTED LOCALITIES OF SLOVAKIA AND POLAND

VPLYV ZRNITOSTI A SPÔSOBU VYUŽÍVANIA PÔDY NA KVANTITU A KVALITU ORGANICKEJ HMOTY PÔDY VO VYBRANÝCH LOKALITÁCH SLOVENSKA A POĽSKA

VLADIMÍR ŠIMANSKÝ[1], ERIKA TOBIAŠOVÁ[1], MICHAŁ JANKOWSKI[2], MACIEJ MARKIEWICZ[2]

[1]Slovak University of Agriculture in Nitra
[2]Nicolaus Copernicus University, Toruń
[1]Slovenská poľnohospodárska univerzita v Nitre
[2]Univerzita Nikolaja Kopernika, Toruń

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The content of soil organic matter in regards to soil texture and land use can be different. We have presumed that the highest soil organic matter content should be noticed in the clayey soils and in native grasslands as well. Therefore, the aim of this study was to characterise soil texture and quantitative and qualitative parameters of soil organic matter and determination of relationship between soil texture and parameters of soil organic matter in generally and with regard to land-use effects. Soil samples were taken from different localities of Slovakia and Poland, always on each locality from arable soil and native grassland. Lesser total (by 25%) and labile (by 13%) carbon contents were determined in intensively cultivated soils in comparison to native grasslands. On the other hand, arable soils had higher quality and stability of soil organic matter than native grasslands. A higher content of sand is the reason of decrease in total organic carbon content ($r = -0.606$, $P < 0.01$). On the other hand, higher content of clay ($r = 0.707$, $P < 0.001$) or silt ($r = 0.483$, $P < 0.05$) is a reason of its increase in soils. A lower content of sand and higher silt content is a reason of increasing soil organic matter stability. The statistically significant effect between soil texture and humic acids stability was observed only in arable soils.

Key words: soil texture, land use, grassland, arable soils, soil organic matter

Soil is not renewable resource, it is affected by degrading factors, which causes for its destruction. Obliteration of soil properties has negative impact on environment and people health. One of the main degradation impacts is land use by agricultural activities and therefore at present time the quantification of soil properties is increasing. Generally, soil quality and its ecological function depends on quantity and quality of soil organic matter.

At last time the decreasing of soil organic matter (SOM) content is reported in literature. Markedly loss of SOM depends on soil type, climate and farming systems (Nardi et al. 2004), soil texture (Needelman et al. 1999; Neufeldt et al. 2002). Several studies (Šimanský et al. 2008; Šimanský and Tobiašová 2007; Nardi et al. 2004) showed on marked effect of soil tillage systems on loss of SOM. Few studies have investigated the influence of soil texture on the relationship between tillage and SOM dynamics. Campbell et al. (1996) reported positive relationship between clay and SOM contents.

Ing. Vladimír Šimanský, PhD., Ing. Erika Tobiašová, PhD., Department of Pedology and Geology, FAFR – Slovak University of Agriculture in Nitra, 949 76 Nitra, Tr. A. Hlinku 2, Slovak Republic. E-mail: Vladimir.Simansky@uniag.sk, Erika.Tobiasova@uniag.sk
Dr. Michal Jankowski, Dr. Maciej Markiewicz, Department of Soil Science, Nicolaus Copernicus University, Toruń, 87-100 Toruń, Gagarina 9, Poland. E-mail: mijank@umk.pl; mawicz@umk.pl

Clay content plays an important role in terms of water retention. Greater water content, resulting from higher clay content in the subsurface horizon of the Ultisols, as well as higher nutrient availability, increases grass productivity and contributes to an increase in SOC (soil organic carbon) storage (Maia et al. 2009). Garcia-Oliva et al. (2006) reported that grassland management affects soil organic carbon (SOC) content and a variety of management options have been proposed to sequester carbon. Ogle et al. (2004) also found that improved grasslands in tropical areas can increase the SOC storage by 17%.

The aim of this study was to characterise the particle-size distribution and quantitative and qualitative parameters of SOM of soil samples collected from different localities of Slovakia and Poland with regard on land-use effects and determination of relationship between soil texture and quantitative and qualitative parameters of soil organic matter also with regard on land-use effects. We hypothesized that: (1) the soils with higher clay content sequester a higher amount of carbon than the soils with dominant portion of sand (2) the highest labile carbon concentration is in native grasslands because of higher SOM content in comparison to arable soils (3) in case of two soils with the same particle-size distribution, but with different land-use effect, in native grasslands will be sequestered more carbon than arable soils.

Table 1

Soil classification

Localities	Soil classification (FAO 2006)
Gniew (Poland)	Haplic Vertisols
Močenok (Slovakia)	Haplic Chernozems
Różankowo (Poland)	Colluvic Regosols
Kráľovský Chlmec (Slovakia)	Eutric Regosols
Toruń, Port Drzewny (Poland)	Eutric Fluvisols
Šaľa (Slovakia)	Calcaric Fluvisols
Drážovce (Slovakia)	Eutric Cambisols
Bukovce (Slovakia)	Dystric Cambisols
Malanta (Slovakia)	Haplic Luvisols
Golianovo (Slovakia)	Haplic Luvisols

MATERIAL AND METHODS

Soils

Soil samples from ten selected localities of Slovakia and Poland from the depth 0–0.3 m were taken, during the years 2006–2008. Before sampling, on each locality were revived two pits (1. arable soil, 2. native grassland). Soils were classified according to WRB (FAO 2006) basing on whole-profile morphology (Table 1). On each locality soil samples from ***a)*** arable soil and ***b)*** native grassland soil were taken. For each sampled zone four different locations were chosen randomly and one average sample by their mixing was created. The twenty soil samples from twenty pits included a large range of parent materials and climates and a large range of soil textures.

Analytical methods

Soil samples were dried at laboratory temperature and grinded. We determined soil texture by pipetting method (Fiala et al. 1999), organic carbon content (C_{ox}) according to Tyurin in modification of Nikitin (Dziadowiec and Gonet 1999) and labile carbon (C_L) by Loginow et al. (1987), fraction composition of humus substances according to Belchikova and Kononova (Dziadowiec and Gonet 1999) and optical parameters of humus substances and humic acids in soil samples. The carbon management index (CMI) was calculated according to Blair et al. (1995) with using following relations:

$$CMI = CPI \times LI \times 100,$$

where CPI is the carbon pool index and LI is the lability index.

CPI and LI are calculated as follows:

$$CPI = \frac{C\ pool\ in\ treatment}{C\ pool\ in\ reference}$$

$$LI = \frac{L\ in\ treatment}{L\ in\ reference}$$

where L refers to the C lability, calculated as:

$$L = \frac{C_L}{C_{NL}}$$

and non-labile carbon (C_{NL}) is calculated as

$$C_{NL} = C_{ox} - C_L$$

where C_{ox} is total carbon content and C_L is labile carbon content.

The native grassland soils were used for each locality as the reference and arable soils as treatment.

Statistical analysis

Analyses of variance (ANOVA) for quantitative and qualitative parameters of soil organic matter (SOM) were performed using Statgraphics Plus. LSD test ($P < 0.05$) was used for means comparison. Correlation analyses were used to assess the relationships between quantitative and qualitative parameters of SOM and soil texture concretely its individual particle size as are: clay (<0.002 mm), silt (0.05–0.002 mm), sand (2–0.05 mm). Significant correlation coefficients were tested on $P < 0.05$.

RESULTS AND DISCUSSION

Soil texture

Soil texture and soil classes according to USDA triangle are presented in Table 2. In Vertisols, the highest clay content (30.71±1.17) and the lowest content of sand (16.41±4.09) were determined. At the same time, we determined the lowest clay content (6.92±4.99) and the highest content of sand (78.91±12.47) in Regosols. Vertisols are textural heavy soils, because they have a high portion of clay particles, which very negatively effects physical and technological properties of soils. Prusinkiewicz (2001) determined more than 50% clay particles in Vertisols in Gniew´s region. In Regosols,

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Soil texture

Localities	Land-use	Particle-size distribution [%]			Soil classes according to USDA triangle (Kolektív 2000)
		sand	silt	clay	
Gniew	native grassland	13.51	54.95	31.54	silty clay loam
	arable soil	19.30	50.82	29.88	silty clay loam
Močenok	meadow	21.01	64.35	14.64	silt loam
	arable soil	25.99	57.43	16.92	silt loam
Różankowo	native grassland	60.53	25.31	14.16	sandy loam
	arable soil	82.21	11.45	6.34	loamy sand
Kráľovský Chlmec	meadow	87.94	8.53	3.53	sand
	arable soil	84.94	11.41	3.66	loamy sand
Toruń, Port Drzewny	native grassland	70.16	13.40	16.44	sandy loam
	arable soil	67.42	23.60	8.97	sandy loam
Šaľa	meadow	41.20	43.28	15.52	loam
	arable soil	26.71	57.08	16.21	silt loam
Drážovce	native grassland	56.93	33.04	10.03	sandy loam
	arable soil	56.19	32.72	11.09	sandy loam
Bukovce	meadow	45.03	29.07	25.90	loam
	arable soil	41.07	39.18	19.75	loam
Malanta	native grassland	26.15	57.76	16.09	silt loam
	arable soil	28.07	54.11	17.82	silt loam
Golianovo	meadow	22.45	54.55	23.00	silt loam
	arable soil	23.50	61.60	14.90	silt loam

the highest sand content was determined, which is typical for this soil type, because of its development on sandy deposits (Bielek et al. 1998). High content of sand particles and relatively low clay content were determined in Cambisols (Table 2). As well as, in Eutric Cambisols in alpine upland clear-cut area, sandy fractions were dominant, which documented the results of Šimanský et al. (2007). Fraction of silt was dominant (57.01±3.47) in Luvisols. Selected soil samples had different soil texture.

Soil organic matter

Soil forming process and land-use effects had the statistically significant influence on the total carbon content (C_{ox}) (Table 3). The highest C_{ox} content was determined in Chernozems, but on the other hand, the lowest C_{ox} was determined in Regosols. If we compare Chernozems and Regosols, we will investigate almost double values, which confirm our hypothesis that higher SOM content is in soils with higher clay content. Results of Neufeldt et al. (2002) showed that SOM contents in the clayey soils were more than twice as high as those in the loamy soils. In intensively cultivated soil (1.44±0.57) in comparison to native grasslands (1.91±0.46) we determined lesser C_{ox} content. Sev-

T a b l e 3

Statistical evaluation of quantity and quality of soil organic matter

Soil organic matter parameters	C_{HA}:C_{FA}	Q_{HS}	Q_{HA}	C_{ox}	C_L	C_{NL}
			Soils			
Vertisols	0.80ab	4.84abc	4.10ab	2.36c	3499b	20051c
Chernozems	1.57c	3.79a	2.99a	2.01bc	2799ab	17322bc
Regosols	0.85ab	5.53bc	4.80b	1.18a	2007ab	9744a
Fluvisols	0.98b	4.69ab	4.30b	1.52ab	1838a	13337abc
Cambisols	0.60a	5.86c	4.68b	1.62abc	2155ab	13996abc
Luvisols	0.72ab	4.55a	4.02ab	1.40ab	1946ab	12004ab
			Land use			
Native grassland	0.85a	5.20b	4.33a	1.91b	2535a	16575b
Arable soil	0.99a	4.55a	3.96a	1.44a	2206a	12243a

C_{ox} – total organic carbon content, C_{HA}:C_{FA} – humic acids to fulvic acids ratio, Q_{HS} – colour quotient humic substances, Q_{HA} – colour quotient humic acids, C_L – labile carbon content, C_{NL} – non-labile carbon content

Different letters (a, b, c) indicate that treatment means are significantly different at $P < 0.05$ according to LSD multiple-range test

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Correlation coeficients in investigated soils

Soil organic matter parameters	C_{ox}	C_L	L	C_{HA}:C_{FA}	Q_{HS}	Q_{HA}
			Soil particles			
Sand	**–0.606**$^{++}$	–0.420	0.296	-0.058	**0.479**$^{+}$	**0.573**$^{++}$
Silt	**0.483**$^{+}$	0.295	–0.285	0.118	**–0.556**$^{+}$	**–0.669**$^{++}$
Clay	**0.707**$^{+++}$	**0.591**$^{++}$	–0.221	–0.106	–0.131	–0.147
<0.01	**0.727**$^{+++}$	**0.539**$^{+}$	–0.318	–0.120	–0.200	–0.276

C_{ox} – total organic carbon content, C_{HA}:C_{FA} – humic acids to fulvic acids ratio, Q_{HS} – colour quotient humic substances, Q_{HA} – colour quotient humic acids, C_L – labile carbon content, L – carbon lability $^{+}P < 0.05$, $^{++}P < 0.01$, $^{+++}P < 0.001$

eral authors also confirmed loss of SOM by intensive tillage systems (Šimanský et al. 2008; Šimanský and Tobiašová 2007; Ogle et al. 2004; Nardi et al. 2004). Results of Barančíková (2002) indicated that higher C_{ox} content was in native grasslands than in arable soils, probably due to reason of a higher roots biomass (Gáborčík et al. 2007), soils can be enriched by roots exudates. Carbon source of root exudates is considerably higher than root biomass (Swinnen et al. 1994).

The total organic carbon content reflected labile (C_L) and non-labile carbon (C_{NL}) contents (Table 3). Soil type had the statistically significant effect on (C_L) and (C_{NL}) contents. We determined a higher content of C_L (by 13%) in native grasslands in comparison to arable soils. That confirms our second guess that the highest C_L contents due to higher portion of roots and root exudates and biomass of micro-organisms should be in native grasslands than in arable soils. Let us assume that into soil is not applied farmyard manure, because as presented Shen et al. (2001) the application of farmyard manure increases C_L content in arable soils. Barančíková (2002) also determined higher C_L contents in native grasslands than in arable soils.

Soil forming process, which is influenced by soil

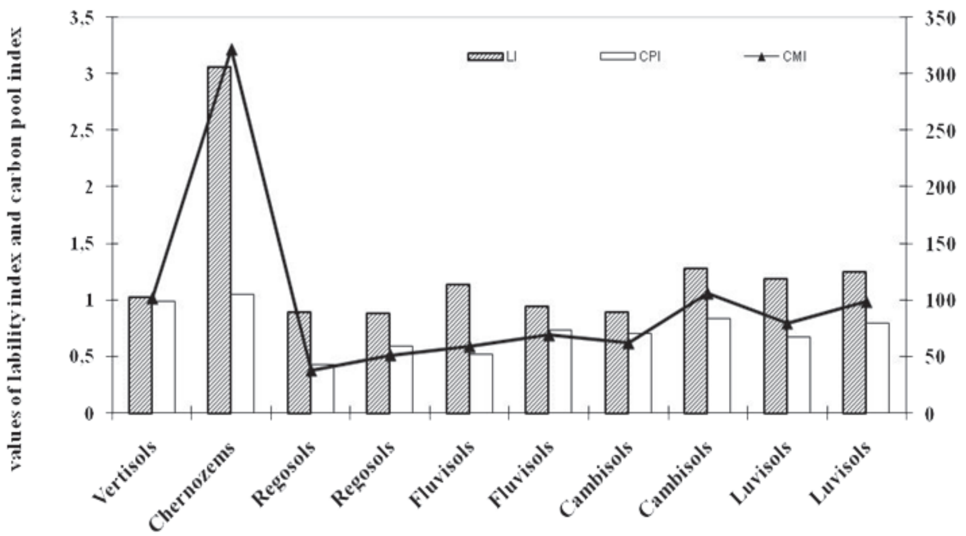

Fig. 1. The values of lability index, carbon management index and carbon pool index in regards on soil types

Table 5

Correlation coefficients in native grasslands or meadows and in arable soils

Soil organic matter parameters	Native grassland						Arable soil					
	C_{ox}	C_L	L	C_{HA}:C_{FA}	Q_{HS}	Q_{HA}	C_{ox}	C_L	L	C_{HA}:C_{FA}	Q_{HS}	Q_{HA}
Soil particles												
Sand	–0.537	–0.086	0.560	–0.222	0.479	0.471	**–0.763**$^{+}$	**-0.654**$^{+}$	0.034	0.081	0.563	**0.727**$^{+}$
Silt	0.445	–0.099	–0.618	0.336	–0.567	–0.606	**0.675**$^{+}$	0.605	0.017	–0.111	–0.577	**–0.748**$^{+}$
Clay	0.547	0.504	–0.196	–0.146	–0.073	0.046	**0.828**$^{+++}$	**0.648**$^{+}$	–0.154	0.027	–0.409	–0.518
<0.01	**0.642**$^{+}$	0.422	–0.357	–0.091	–0.191	–0.155	**0.839**$^{+++}$	0.615	0.231	–0.098	–0.347	–0.504

C_{ox} – total organic carbon content, C_{HA}:C_{FA} – humic acids to fulvic acids ratio, Q_{HS} – colour quotient humic substances, Q_{HA} – colour quotient humic acids, C_L – labile carbon content, L – carbon lability $^{+}P < 0.05$, $^{++}P < 0.01$, $^{+++}P < 0.001$

substrate, climate, organisms, water and cultivation, had the statistically significant effect on qualitative parameters of SOM (Table 3). The highest difference in quality of SOM based on the C_{HA}:C_{FA} was observed between Chernozems and Cambisols. The highest SOM stability (Q_{HS} = 3.79, Q_{HA} = 2.99) was observed in Chernozems, but on the other hand the lowest stability of humic substances was determined in Cambisols (Q_{HS} = 5.86). In regard to land-use effect the large differences were observed, as well. Arable soils in comparison to native grasslands had a higher quality and stability of SOM (Table 3). Observed results are in conformity with several published studies (Barančíková 2002; Šimanský et al. 2007; Nardi et al. 2004).

In soil types, the values of lability index (LI) were different. The highest LI values were investigated in Chernozems (3.06) and Vertisols (1.03), but also relatively high LI were in Cambisols and Luvisols (Fig. 1), which correlate with C_L contents (Table 3). It means that SOM is more labile in mentioned soil types, due to application of farmyard manure and crop residues into soil (Shen et al. 2001; Tobiašová and Šimanský 2009). The soil organic carbon (SOC) pool and the C lability directly influence soil physical, chemical and biological attributes as well as the self-organization capacity of soils. Therefore, the integration of both SOC pool and C lability into the carbon management index (CMI), originally proposed by Blair et al. (1995), can provide a useful parameter to assess the capacity of management systems into promote soil quality. We calculated carbon pool index (CPI) according to Blair et al. (1995). CPI values indicated the fact from the point of view SOM reduction that its relatively large degradation was in Regosols and Fluvisols (Fig. 1), duo to great sand content in both soil types (Table 2). In mentioned soil types, the lowest CMI values were calculated. It means that SOM underlies to changes due to intensive cultivation.

Effect of soil texture on soil organic matter

Soil texture influenced SOM (Table 4). We detected the statistically significant correlations between C_{ox} and individual soil particles. Obtained results showed on fact that in soil a higher content of sand was the reason of decrease of C_{ox} (r = –0.606, $P < 0.01$). On the other hand, a higher content of clay (r = 0.707, $P < 0.001$) or silt (r = 0.483, $P < 0.05$) is the reason of C_{ox} increase in soils. It is in agreement with results of Neufeldt et al. (2002). Arable soils were more influenced in comparison to native grasslands (Table 5), which confirm our guess. Here are few reasons: in arable soils give out by the cultivation to intensive aeration with following more intensive mineralization (Šimanský et al. 2008; Ogle et al. 2004; Nardi et al. 2004) and also in sandy soils (cultivated) is more intensive mineralization (Campbell et al. 1996). On sandy soils which are used as native grasslands the loss of C_{ox} is not intensive, because of natural soil surface and also there is not intensive aeration. As well, we detected positive correlation relationships between C_L and soil particles as <0.01 mm, <0.001 mm (Table 4). A negative correlation between C_L and sand content (r = –0.654, $P < 0.05$) as well as a positive correlation of C_L with clay content (r = 0.648, $P < 0.05$) were determined in arable soils in comparison to native grasslands. Soil texture had not influences on SOM quality, on the other hand, a lower content of sand and higher silt content is a reason of increasing SOM stability in soils (Table 4). The statistically significant effect between soil texture and humic acids stability was observed only in arable soils (Table 5).

CONCLUSION

All in all, we summarize that in intensively cultivated soil lesser total and labile carbon contents was determined in comparison to native grasslands. On the other hand, arable soils had higher quality and stability of soil organic matter than native grasslands.

Obtained results show on fact that in the soils a higher content of sand is the reason of decrease in total and labile carbon contents, but a higher content of clay or silt is the reason of their increase. A lower content of sand and higher silt content is the reason of increasing soil organic matter stability in soils. Arable soils were more influenced than native grasslands.

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SÚHRN

Obsah organickej hmoty pôdy môže byť v závislosti od zrnitostného zloženia a rozdielneho využívania odlišný. Vychádzali sme z predpokladu, že vyšší obsah organickej hmoty bude v pôdach s vyšším obsahom ílu a taktiež v pôdach, ktoré sú využívané ako lúky. Charakterizované bolo zrnitostné zloženie a kvantitatívne a kvalitatívne parametre organickej hmoty vybraných pôd Slovenska a Poľska. Medzi jednotlivými zrnitostnými frakciami a parametrami organickej hmoty pôdy sme určili ich vzájomné vzťahy aj v závislosti od spôsobu využívania pôdy. Pôdne vzorky na každej lokalite sme vždy odobrali z obrábanej pôdy a z lúky. V intenzívne obrábaných pôdach bol stanovený o 25 % menší obsah celkového a o 13 % menší obsah labilného uhlíka v porovnaní s pôdami, ktoré sa využívali ako lúky. Na druhej strane kvalita a stabilita organickej hmoty bola vyššia v obrábaných pôdach. Čím je vyššie zastúpenie frakcie piesku v pôde, tým dochádza k intenzívnejšej strate celkového organického uhlíka (r = −0,606; P < 0,01). Vysoký obsah frakcie ílu (r = 0,707; P < 0,001), ale aj prachu (r = 0,483; P < 0,05) sa podieľa na zadržiavaní uhlíka v pôdach. Nízky obsah piesku a vysoký obsah prachovej frakcie významne ovplyvnili stabilitu organickej hmoty sledovaných pôd, pričom výraznejší efekt bol pozorovaný v obrábaných pôdach.

Kľúčové slová: zrnitosť pôdy, využívanie pôdy, lúky, obrábané pôdy, organická hmota pôdy