

The effect of land use on the soil carbon, total and extractable SOM

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One of the main objectives of this work was to study the effects of land use on soil carbon, total and extractable SOM and the properties of humic substances. Soil samples were collected in western and central Lithuania and represented *Albeluvisol* and *Cambisol*. Total C contents as well as C / N in the soil samples were determined by a dry combustion method using an automatic Vario EL III analyzer. Extractable SOM was measured using sodium pyrophosphate solution and hot water for the extraction procedure. Humic acids were investigated by the methods of gel permeation chromatography and absorption spectroscopy in UV / VIS and IR regions. Experimental evidence suggests that land use conversion had both positive and negative effects on soil total and extractable carbon and SOM. In *Albeluvisols*, grassland soil was found to contain by 0.2–0.6 g kg⁻¹ more C compared to fallow land (1–1.5 years old). In *Cambisols*, long-term pasture soil was found to contain by 2.4 g kg⁻¹ more C compared to arable land (16 years) converted from pasture. Results of humic acid analyses by gel chromatography showed a high molecular weight and polydispersity of humic acids. The highest content of humic acids in HWE as well as a high content (29%) of macromolecules with the molecular weight more than 100,000, and the lowest C / N ratio (10.3) were determined in long-term pasture soil.

Key words: soil carbon, SOM, extractable SOM, *Albeluvisol*, *Cambisol*, land use, grassland, fallow

INTRODUCTION

Soil carbon (C) and soil organic matter (SOM) play a fundamental role in sustaining soil and environmental quality. SOM has been increasingly recognized as an indicator of soil quality, that is, a component of biosphere sustainability and stability (Kogut, 1998). Soil C in agricultural soils is of increasing interest. However, there is little experimental evidence on C and both total and extractable SOM in differently used agricultural land, especially those describing changes resulting from land use conversion. Ideal settings to sequester organic carbon in soils are found in the environments that promote minimum soil disturbance (Post et al., 2001). Land use has an influence on the biomass stock of ecosystems (Schimel, 1995). A change in land use

from forest or grassland to cropping will, therefore, generally lead to a loss of soil carbon (Whitbread et al., 1998; Murty et al., 2002). Conversion of cropland to alfalfa resulted in a greater SOC as well as N accumulation in the 0–5 cm layer. Soil C / N ratios tended to increase in grassland (alfalfa) soils compared with crop soils (Su, 2007). In extensively used grassland, 42% of Austria's total soil Corg pool is stored (Gerzabek et al., 2001). To compare with a presently non-cultivated farmland, in pine plantations organic carbon pool was more than 6-fold higher in the upper 10 cm layer including the O horizon (Armolaitis ir kt., 2005). Significantly higher SOM values in *Albeluvisols* were found under grass–grain crop rotations on 2–5° and 5–10° slopes compared with the the field crop rotation (Jankauskas et al., 2005). Land use is considered to be an important factor

influencing soil carbon variation and properties of humic substances. However, there is little experimental evidence about the molecular weight and spectroscopical properties of humic acids in differently used agricultural land.

The aim of this work was to study the effect of land use on soil carbon, total and extractable SOM and the properties of humic substances.

MATERIALS AND METHODS

Soil samples from the 0–30 cm layer at three field replicates of each plot were taken in 2007 in Šilutė, Šilalė and Kėdainiai regions of Lithuania. Soil samples were dried and milled using a ZM 200 ultracentrifugal mill equipped with a 0.2 mm sieve. Part of samples (6–11) represented *Albeluvisols*, and the other part (15–16, 19, 21) were *Cambisols*. Carbon content in all samples was determined by the dry combustion method using an automatic Vario EL III analyzer (Elementar, Germany). SOM was calculated by multiplying the SOC content determined using wet oxidation by the factor $f = 1.724$. Part of soil organic matter was measured by the parameter of hot water extractable (HWE) fraction as a very easily decomposable SOM. This fraction was extracted with distilled water (1 / 5, w/v) under reflux boiling for 1 h. In the membrane-filtered extract, humic acids (HA) were determined using HA standard solution by a spectrophotometrical procedure using Carry 50 at 450 nm. Humic substances were also extracted from soil using sodium pyrophosphate solution. HA were investigated by the methods of gel permeation chromatography and absorption spectroscopy in the visible region. The molecular weight distribution of HA was determined using gel permeation chromatography on Sephadex G-100 (Pharmacia, Sweden) with the application of 0.05 M Tris-HCl-buffer at pH 9.0

as the eluent. The formula of Determan was used for estimating the average apparent molecular weight of the fractions. The relative contents of the molecular weight fractions of HA were estimated from the areas under corresponding peaks on the curves of their molecular weight distribution. Optical densities of HA at 465 nm (D465) and 665 nm (D665) in 0.1 M NaOH were measured and the E4 / E6 ratios calculated.

The experimental data were processed by STAT ENG (Tarkanovas, Raudonius, 2003).

RESULTS AND DISCUSSION

The content of carbon in *Albeluvisols* ranged within 14.0–28.3 g kg⁻¹ and in *Cambisols* within 19.8–22.2 g kg⁻¹ in agricultural soils and was much higher (68.1 g kg⁻¹) in a flower garden fertilised with peat litter (Table 1). Land use conversion was found to have both positive and negative effects on soil carbon.

Results presented in Fig. 1 indicate that in *Albeluvisol* the content of SOM accumulated in grassland was by 2% higher (in relative values) compared with fallow land. In *Cambisol*, the SOM content was as high as 111.0 g kg⁻¹ in a flower garden fertilised with peat litter. In the arable land converted from pasture, SOM content decreased from 38.9 g kg⁻¹ to 27.4 g kg⁻¹, i. e. by 29.6%, expressed in relative values.

The lowest C/N ratio (10.3) was determined in the long-term pasture (*Cambisol*) (Table 2).

The contents of humic acids determined in HWE are presented in Table 3. The lower content of humic acids in HWE was determined in the Kalniškė–Jurgaičiai forest (154 mg l⁻¹) compared with that in the agricultural land situated in the vicinity of the forest (173–189 mg l⁻¹).

Table 1. Carbon content in differently used soils

Laboratory mark of a sample	Site	Land use	C g kg ⁻¹	SE ±
6	Šilutė region, Nikėlai	Fallow	27.7	1.7
7	Šilutė region, Nikėlai	Grassland	28.3	1.9
8	Šilutė region, Kalniškė–Jurgaičiai	Forest	19.8	2.4
9	Šilutė region, Palendriai	Fallow	14.0	0.6
10	Šilutė region, Palendriai	Pastured grassland	14.2	1.7
11	Šilalė region, Kaltinėnai	Arable land	14.1	1.5
15	Kėdainiai region, Dotnuva	Long-term pasture	22.2	0.6
16	Kėdainiai region, Dotnuva	Arable land converted from pasture	19.8	1.3
21	Kėdainiai region, Dotnuva	Flower garden fertilised with peat litter	68.1	9.3

Table 2. C / N ratio in differently used soils

Laboratory mark of a sample	Site	Land use	C / N ratio	SE ±
6	Šilutė region, Nikėlai	Fallow	14.7	1.8
7	Šilutė region, Nikėlai	Grassland	15.0	1.3
8	Šilutė region, Kalniškė–Jurgaičiai	Forest	15.9	4.6
9	Šilutė region, Palendriai	Fallow	10.8	0.7
10	Šilutė region, Palendriai	Pastured grassland	11.0	1.3
15	Kėdainiai region, Dotnuva	Long term pasture	10.3	0.9
21	Kėdainiai region, Dotnuva	Flower garden fertilised with peat litter	16.2	0.8

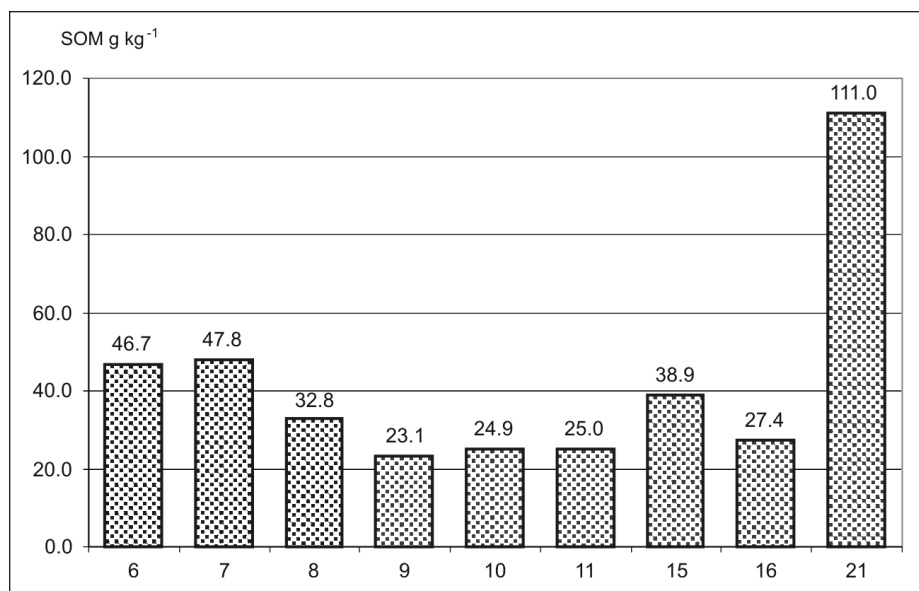


Fig. 1. SOM content in differently used soils
Note. Numbers on the x axis correspond to sample marking shown in Table 1.

Table 3. Humic acids in hot water extract in differently used soils

Laboratory mark of a sample	HA mg L ⁻¹	SE ±
6	234	8
7	205	25
8	154	48
9	173	32
10	189	7
15	447	46
16	241	39
21	235	39

Note. Numbers in the first column correspond to sample marking shown in Table 1.

Table 4. Molecular weight (MW) of and part of fractions (in %) of humic acids

Laboratory mark of the sample	Fraction 1		Fraction 2	
	MW, Da	%	MW, Da	%
HA6	≥ 100,000	20	22 340	80
HA7	≥ 100,000	16	24 430	84
HA8	≥ 100,000	23	26 180	77
HA9	≥ 100,000	20	15 240	80
HA10	≥ 100,000	20	20 650	80
HA15	≥ 100,000	29	18 280	71
HA16	≥ 100,000	25	18 790	75
HA21	≥ 100,000	40	36 980	60

Note. Humic acids are marked according to sample marking shown in Table 1.

Results of the analysis of humic acids extracted with phyrophosphate solution by gel chromatography show a high molecular weight and polydispersity of the humic acids (Table 4).

The molecular weight of humic acids has been shown to be an important factor in controlling organic matter sorption to soil minerals (Guo, Chorover, 2003; Ohno, 2007).

All humic acids (HA) made up two major fractions (Fraction 1 and Fraction 2). The macromolecular Fraction 1 was characterised by MW ≥ 100 000, its content in the

samples varied within 16–40%. The content of the low molecular weight Fraction 2 characterised by MW from 15,240 to 36,980 varied within 60–80%. All the HA under investigation are characterized by the bimodal distribution of macromolecules with the predominance (60–84%) of a less MW fraction with an average molecular weight ranging from 15,240 to 36,980. Optical density D₄₆₅, as well as the E₄ / E₆ ratio were considered to characterize the degree of aromatic condensation and poly-conjugation in the humic molecules (Table 5).

A higher value of D₄₆₅ usually corresponds to a higher degree of aromatic poly-conjugation and, consequently, to a higher degree of humification and chemical maturity of HA. Absorbance at 465 nm expresses the presence of the initial humification stage, and absorbance at 665 nm indicates the presence of humic acids formed in well-humified organic matter (Debska, 2002). Analysis of data obtained during this study leads to the following conclusions on the chemical structure and molecular parameters of the HA studied (Table 6). HA6, HA7, HA9 and HA10 can be regarded as the most chemically mature HA in the study. They are characterized by a significant predominance of the lower molecular weight fraction (80–84%). The high values of D₄₆₅ (0.618–0.671) reflect a high degree of aromatic poly-conjugation in their molecules. HA16 has a little lower contribution of the lower molecular weight fraction com-

Table 5. Parameters of spectra in the visible region of HA in differently used soils

Sample	D ₄₆₅	D ₆₆₅	E ₄ /E ₆
HA6	0.671	0.148	4.53
HA7	0.632	0.140	4.51
HA8	0.459	0.094	4.88
HA9	0.618	0.153	4.04
HA10	0.626	0.154	4.06
HA15	0.474	0.106	4.47
HA16	0.559	0.131	4.27
HA21	0.488	0.115	4.24

Note. Humic acids are marked according to sample marking shown in Table 1.

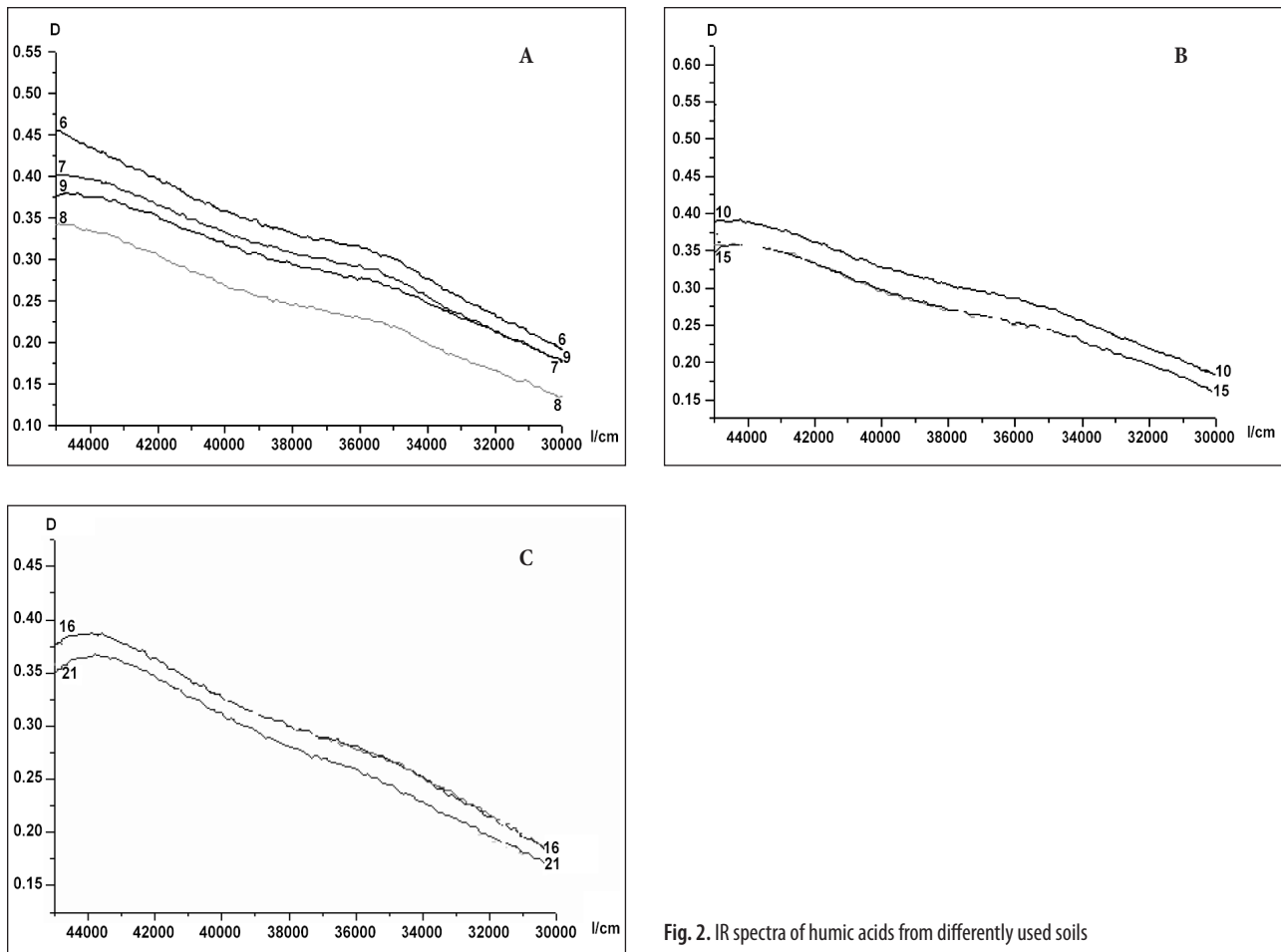


Fig. 2. IR spectra of humic acids from differently used soils

pared with the former HA (73–77%), less developed systems of aromatic poly-conjugation ($D_{465} = 0.559$ and 0.585) and a higher content of polypeptides in its molecules. HA8, HA15, and especially HA21 have a higher content of macromolecules with the molecular weight more than 100,000. They are characterized by less developed systems of poly-conjugation ($D_{465} = 0.441$ – 0.488) under study. Figures 2 A, B, C show the differences in IR spectra of HA extracted from differently used soils.

CONCLUSIONS

Experimental evidence suggests that land use conversion had both positive and negative effects on soil total and extractable carbon. In *Albeluvisols*, the grassland soil (0–30 cm layer) was found to contain by 0.2 – 0.6 g kg^{-1} more C compared to fallow land (1–1.5 years old). In *Cambisols*, long-term pasture soil was found to contain by 2.4 g kg^{-1} more C compared to arable land converted from pasture. Results of humic acids analyses by gel chromatography showed a high molecular weight and polydispersity of humic acids. The highest content of humic acids in HWE as well as a high content (29%) of macromolecules with the molecular weight more than 100,000, and the lowest C / N ratio (10.3) were determined in long-term pasture soil (*Cambisol*). Conversion of grasslands and pastured grasslands into fallows and arable lands leads to a transformation of HA in

the direction of increasing the degree of their chemical maturity. The introduction of peat litter into the soil of a flower garden increased the process of humification with the formation of young immature HA.

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ŽEMĖNAUDŲ ĮTAKA DIRVOŽEMIO ANGLIAI, SUMINEI IR IŠEKSTRAHUOTAI ORGANINEI MEDŽIAGAI

Santrauka

Dirvožemio anglis (C) ir dirvožemio organinė medžiaga (DOM) turi fundamentinę reikšmę dirvožemio tausojimui ir aplinkos kokybei. Vienas pagrindinių šio darbo tikslų buvo žemės naudojimo įtakos dirvožemio angliai – suminei ir ištraukose – bei humuso rūgščių savybių įvertinimas. Dirvožemio mėginiai (*Albeluvisol* ir *Cambisol*) surinkti Lietuvos vidurinėje ir vakarinėje dalyse. C bei C/N dirvožemio mėginiuose nustatyta sauso deginimo metodu automatinio analizatoriaus Vario EL III. Tirpi DOM nustatyta natrio pirofosfato ir vandeninėje ištraukose. Humuso rūgščių preparatai ištirti gelių chromatografijos, absorbcinės spektroskopijos UV/VIS ir IR srityse metodais. Gauti tyrimų duomenys, kad žemės naudojimo konversija turėjo tiek teigiamos, tiek neigiamos įtakos dirvožemio angliai ir organinei medžiagai. Dirvožemyje (*Albeluvisol*) su žolynais buvo 0,2–0,6 g kg⁻¹ daugiau anglies, negu dirvožemyje su juoduoju pūdymu (1–1,5 m). *Cambisol* dirvožemyje ilgalaikėje ganykloje buvo 2,4 g kg⁻¹ daugiau C, negu prieš 16 m. suartoje ganykloje, dabartiniame sėjomaininiame plote. Humuso rūgščių tyrimai atskleidė jų polidispersiškumą, didelį molekulinį svorį. Sauriausias C/N santykis (10,3), didžiausias humuso rūgščių kiekis karšto vandens ištraukoje, didelė dalis (29%) makromolekulių, kurių molekulinis svoris didesnis už 100 000, nustatyta ilgalaikių ganyklų dirvožemyje.

Raktažodžiai: anglis, dirvožemio organinė medžiaga (DOM), tirpi DOM, balkšvažemiai, rudžemiai, žemėnauda, žolynai, pūdymas