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EFFECT OF LAND USE ON THE CARBON AND NITROGEN FORMS IN HUMIC HORIZONS OF STAGNIC LUVISOLS

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Abstract

The aim of the study was to assess the effect of land use on the forms of carbon and nitrogen in humic horizons of Stagnic Luvisols located in the area of Sławieńska Plain (northern Poland). Soil samples were collected form six stands with different land uses located in the same soil complex: more than 100-year-old beech-oak forest (BOF), meadow (M), arable field (AF), fallow (F), secondary afforestation with 15- year-old birch trees (SAB) and secondary afforestation with 30-year-old alder trees (SAA). In every stand, soils were sampled in five replications and analyzed with standard methods used in soil science. The content of different forms of carbon and nitrogen was analyzed after sequential extraction in 0.25 mol KCl dm^{-3}, 0.25 mol H_2SO_4 dm^{-3} and 2.5 mol H_2SO_4 dm^{-3} (Becher, Kalembasa 2011). Different land uses were reflected in the properties of humic horizon of the investigated soils. Particularly large differences were observed between the forest soils never used for agriculture, and arable or post-arable soils. Tillage caused the increase of the A horizon depth from 9.2 to 26.4-35.6 cm, and the increase of its volumetric density. The highest content of soil organic matter (SOM), total organic carbon (TOC) and total nitrogen (TN) as well as the highest TOC:TN ratio were observed in BOF stand. Statistically significant differences were observed between the stands in the content of carbon forms. Nonhydrolyzable carbon was dominat in the soils (55.98-68.11% of TOC), and dissolved organic carbon (DOC) had the smallest contribution (1.43-3.70% in TOC). In general, higher contribution of DOC in TOC was observed in arable and post-arable soils than in soils under forest. The content of mineral nitrogen (NO_3-N + NH_4-N) in the studied soils ranged from 0.028 to 0.053 g kg^{-1}, and NH_4-N dominated in the pool. The lowest concentration of mineral nitrogen was observed in arable soils, and significantly higher in the soils under forest and fallow. Easily hydrolyzable nitrogen (EHN), weakly hydrolyzable nitrogen (WHN) and nonhydrolyzable nitrogen (NHN) were the main forms of the element in the studied soils and their content was closely related to the content of SOM. The highest concentration of the forms was noticed in BOF stand. There were differences between the stands in DOC:DON, EHC:EHN, WHC:WHN and NHC:NHN ratios, which indicate varied biological activity of the soils under different uses.

Key words: carbon forms, nitrogen forms, Stagnic Luvisols, arable soils, forest soils, Sławieńska Plain.

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WPŁYW SPOSOBU UŻYTKOWANIA NA FORMY WĘGLA I AZOTU W POZIOMIE PRÓCHNICZNYM GLEB PŁOWYCH STAGNOGLEJOWYCH

Abstrakt

Celem pracy była ocena wpływu sposobu użytkowania na zawartość i udział form węgla i azotu w poziomie próchnicznym gleb płowych stagnoglejowych położonych na obszarze Równiny Sławieńskiej (północna Polska). Próbki gleb pobrano z 6 stanowisk użytkowanych w różny sposób, położonych w obrębie tego samego kompleksu gleb. Stanowiska obejmowały: ponad 100-letni las bukowo-dębowy (BOF), łąkę (M), pole uprawne (AF), ugór (F), oraz 15-letnie zalesienie brzozą (SAB) i 30-letnie zalesienie olchą (SAA) na gruntach porolnych. Próbki gleb na każdym stanowisku pobrano w 5 powtórzeniach. Oznaczono w nich właściwości fizyczne i chemiczne, stosując metody powszechnie stosowane w gleboznawstwie, oraz zawartość form węgla i azotu w roztworach po sekwencyjnej ekstrakcji z zastosowaniem 0,25 mol KCl dm^{-3}, 0,25 mol H_2SO_4 dm^{-3} i 2,5 mol H_2SO_4 dm^{-3} (Becher, Kalembasa 2011). Stwierdzono istotny wpływ sposobu użytkowania gleb na właściwości poziomu próchnicznego badanych gleb. Szczególnie duże różnice notowano między nigdy nie użytkowanymi rolniczo glebami leśnymi a glebami rolnymi i porolnymi. Użytkowanie rolnicze gleb spowodowało wzrost miąższości poziomu A z ok. 9,2 cm do 26,4-35,6 cm oraz zwiększenie gęstości objętościowej w tym poziomie. W glebach leśnych obserwowano największą zawartość materii organicznej (SOM), węgla organicznego (TOC) i azotu ogółem (TN), a także najszerszy stosunek TOC: TN. Stwierdzono istotne statystycznie różnice między glebami na badanych stanowiskach pod względem zawartości różnych form węgla. Dominującą frakcją był węgiel nie ulegający hydrolizie (55,98-68,11% TOC), najmniejszy zaś udział miał rozpuszczalny węgiel organiczny (DOC) – 1.43-3.70% TOC. Na ogół większy udział DOC w TOC notowano w glebach rolnych i porolnych w porównaniu z glebami leśnymi. Zawartość azotu mineralnego (NO_3-N + NH_4-N) wynosiła 0,028-0,053 g kg^{-1}. W tej puli dominowała forma amonowa. Najniższe stężenie azotu mineralnego odnotowano w glebach ornych i istotnie wyższe w glebach leśnych oraz ugorowanych. W badanych glebach dominowały formy azotu łatwo hydrolizująca (EHN), trudno hydrolizująca (WHN) i niehydrolizująca (NHN), występując w zbliżonych proporcjach. Ich zawartość była pozytywnie skorelowana z zawartością materii organicznej, więc największe stężenie tych form występowało w glebach na stanowisku BOF. Stwierdzono różnice między stanowiskami pod względem stosunków DOC:DON, EHC:EHN, WHC:WHN i NHC:NHN, co świadczy o zróżnicowanej aktywności biologicznej gleb użytkowanych w różny sposób.

Słowa kluczowe: formy węgla, formy azotu, gleby płowe stagnoglejowe, gleby uprawne, gleby leśne, Równina Sławieńska.

INTRODUCTION

The quantity and quality of SOM varies across space and time and is a result of the influence of many environmental and anthropogenic factors (cf. Chertov, Komarov 1997, Pulleman et al. 2000, Kužel et al. 2001, Kwiatkowska, Maciejewska 2003, Bejger, Gołębiowska 2005, Dziadowiec, Lutowska 2005, Dziamski et al. 2005, Szombathova et al. 2005, Tobiasova et al. 2005, Gondek 2007, Gonet, Dębska 2007, Simansky 2007, Łabaz et al. 2011, Kalembasa, Becher 2012). SOM represent different forms – from fresh litter fall, through humic substances to easily soluble organic components, like amino acids or carbohydrates. Microorganisms play an important role in the processes of SOM transformation, and dissolved organic matter (DOM) is a product of their activity. The biological activity of soil and the intensity of DOM production are strongly affected by soil properties (especially pH, moisture, the content of available forms of nutrients, pollution with heavy metals), weather conditions and other factors (Hue et al 1986, Qualls, Haines 1991, Cotrufo et al 1995, Christ, David 1996, Murphy et al. 2000, Anderson et al. 2002, Smolander, Kitunen 2002, Fröberg et al. 2005, Dawson et al. 2008, Schmidt, Glaser 2011). Carbon, hydrogen, oxygen and nitrogen are the main components of SOM. The percentage of carbon in SOM is always about 50%, but the content of nitrogen is varied, which is reflected in differentiated C:N ratios. The type of land use is one of the most important factors affecting the content and contribution of different forms of carbon and nitrogen in the soil, as well as intensity of leaching of their labile forms (Lipiec, Stępniewski 1995, Murphy et al 2000, Jonczak, Parzych 2012).

The aim of the study was to assess the influence of land use type (from beech-oak forest, through meadow, arable field, fallow to secondary afforestation with birch and alder) on carbon and nitrogen forms in humic horizons of Stagnic Luvisols.

MATERIAL AND METHODS

The studies were conducted in northern Poland, in the area of Sławieńska Plain, near Stary Kraków (54°26′N; 16°36′E). The investigated Stagnic Luvisols were formed from glacial till of the Pomeranian phase of Baltic glaciation. Spatial variability in the character of land use type was observed within the investigated soil complex. Soil samples were collected in April 2012 from six stands with different land uses: more than 100-year-old beech -oak forest (BOF), meadow (M), arable field (AF), fallow (F), post-arable afforestation with 15- year-old birch (SAB) and post-arable afforestation with 30-year-old alder (SAA). In every stand, soil was sampled in five replications as monoliths from the A horizons and as volumetric samples using 100 cm^3 steel rings from central parts of the horizon. The samples were dried at 40°C, passed through a 2 mm sieve and analyzed. The following soil properties were analyzed:

– texture with mixed pipette and sieve methods (textural fractions and groups were taken after classification of Polish Society of Soil Science 2008);
– volumetric density with gravimetric method using 100 cm^3 steel rings;
– the content of water (% v/v) in volumetric samples with gravimetric method;
– pH potentiometrically (Elmetron CP-401) in water and 1 mol KCl dm^{-3} in a 1:2.5 ratio;
– the content of soil organic matter (SOM) as loss on ignition at 550°C;
– the content of total organic carbon (TOC) with the Tiurin method;

– the content of total nitrogen (TN) with the Kjeldahl method using a VELP UDK-127 distilling unit;
– the content of carbon and nitrogen forms after sequential extraction in 0.25 mol KCl dm^{-3}, 0.25 mol H_2SO_4 dm^{-3} and 2.5 mol H_2SO_4 dm^{-3} (BECHER, KALEMBASA 2011).

Based on the extractions, the following fractions of carbon and nitrogen were isolated:

– dissolved organic carbon (DOC) – after extraction with 0.25 mol KCl dm^{-3};
– easy hydrolyzable carbon (EHC) – after extraction with 0.25 mol H_2SO_4 dm^{-3};
– weakly hydrolyzable carbon (WHC) – after extraction with 2.5 mol H_2SO_4 dm^{-3};
– nonhydrolyzable carbon (NHC) – was calculated as TOC-DOC-EHC-WHC;
– nitrate nitrogen (NO_3-N) – after extraction with 0.25 mol KCl dm^{-3};
– ammonium nitrogen (NH_4-N) – after extraction with 0.25 mol KCl dm^{-3};
– dissolved organic nitrogen (DON) – the content of the Kjeldahl nitrogen after extraction with 0.25 mol KCl dm^{-3} – NH_4N;
– easy hydrolyzable nitrogen (EHN) – after extraction with 0.25 mol H_2SO_4 dm^{-3};
– weakly hydrolyzable nitrogen (WHN) – after extraction with 2.5 mol H_2SO_4 dm^{-3};
– nonhydrolyzable nitrogen (NHN) – was calculatedas TN-NH_4-N –DON–EHN-WHN.

The content of carbon in the extracts was analyzed with the Tiurin method after the evaporation of a sample, NO_3-N – colorimetrically with sodium salicylate, NH_4-N – by distillation using a VELP UDK-127 distilling unit, and organic nitrogen – by the Kjeldahl's method using a VELP UDK-127 distilling unit.

Mean concentrations of analyzed components were calculated for each stand and differences between the stands were tested with the *T*-Student test. Correlation coefficients between the content of the forms of carbon and nitrogen and some properties of the soils were calculated.

RESULTS AND DISCUSSION

The results of many studies show that a land use type in one of the most important factors affecting soil properties, especially stocks and properties of SOM, and nutrient cycling in ecosystems (CHESHIRE et al. 1992, HU et al. 1997, MANDER et al. 2000, NIEDER, RICHTER 2000, KLIMOWICZ, UZIAK 2001, SIMANSKY 2007, SIENKIEWICZ et al. 2009, DOMAGAŁA-ŚWIĄTKIEWICZ, SADY 2011). The results of the current studies show changes in some properties of the A horizons of Stagnic Luvisols under different land uses – from forest soils never used for agriculture (BOF), through arable soils (M, AF) and fallow (F) to the secondary afforestation with birch (SAB) and alder (SAA). Different land uses were reflected in the physical and chemical properties of the A horizons of the soils, as well as in the content and contribution of the forms of carbon and nitrogen. The soils in BOF stand were characterized by the smallest thickness of the horizon (9.2 cm) and its volumetric density (0.84 g cm^{-3}). The A horizon thickness in the remaining stands was affected by tillage and ranged from 26.4 cm to 35.6 cm (Table 1). The highest volumetric density was observed in the soils of AF (1.59 g cm^{-3}) and SAB stands (1.53 g cm^{-3}), slightly lower in M (1.38 g cm^{-3}) and F (1.41 g cm^{-3}) and significantly lower in SAA stand (1.17 g cm^{-3}). Volumetric density can strongly influence the uptake and loss of the elements, especially nitrogen (LIPIEC, STĘPNIEWSKI 1995). The soils in general were acid, but the pH varied from 4.05 in BOF stand to 6.25 in M stand. The higher values of pH observed in arable soils are the result of fertilization. The soils of BOF stand were the richest in SOM (107.3 g kg^{-1}), TOC (51.2 g cm^{-3}) and TN (3.05 g cm^{-3}). The content of SOM in the remaining stands was 26.3-48.9 g cm^{-3}, TOC 9.2-21.4 g cm^{-3} and TN 0.82-1.60 g cm^{-3}. TOC:TN ratios ranged from 11.3:1 in SAB stand to 16.8:1 in BOF stand (Table 1). The observed TOC:TN ratios indicate relatively good conditions of soil organic matter mineralization.

Labile forms of organic carbon, whose content is a good indicator of soil quality as influenced by changes in management practices (LAIK et al. 2009),

Table 1

Selected properties of the A horizon of the soils (mean±SD)

Soil properties	BOF	M	AF	F	SAB	SAA
Thickness of A horizon (cm)	9.2±0.8	31.6±3.2	26.4±5.8	30.4±3.7	35.6±2.6	28.4±2.5
Soil texture group	sand	sandy loam	sandy loam	sandy loam	sandy loam	sandy loam
Sand (%)	83.9	61,0	50.9	64.0	66.3	66.0
Silt (%)	16.1	36.9	43.4	34.8	30.8	33.3
Clay (%)	0.0	2.1	5.7	1.2	2.9	0.7
Volumetric density (g cm^{-3})	0.84±0.09	1.38±0.02	1.59±0.06	1.41±0.17	1.53±0.07	1.17±0.10
Water content (% v/v)	31.8±2.2	34.6±2.1	28.2±1.6	27.6±3.1	25.0±1.4	38.4±5.0
pH_{H2O}	4.05±0.17	6.25±0.12	6.01±0.18	5.62±0.40	5.12±0.17	4.23±0.11
SOM (g kg^{-1})	107.3±31.3	33.7±2.1	43.3±3.3	36.3±0.7	26.3±1.8	48.9±9.0
TOC (g kg^{-1})	51.2±13.5	13.2±0.6	16.0±2.7	12.8±0.7	9.2±0.8	21.4±5.1
TN (g kg^{-1})	3.05±0.82	1.12±0.02	1.22±0.10	1.12±0.12	0.82±0.11	1.60±0.28
TOC:TN	16.8±0.6	11.8±0.6	13.0±1.5	11.4±1.0	11.3±0.9	13.4±1.3

Table 2

The content of carbon forms in soil under different land use

Carbon form		BOF	M	AF	F	SAB	SAA
DOC	g kg^{-1}	0.71	0.34	0.33	0.33	0.34	0.40
	% in TOC	1.43	2.57	2.08	2.57	3.70	1.89
EHC	g kg^{-1}	11.33	3.05	3.48	2.82	2.17	5.00
	% in TOC	22.65	23.13	21.81	22.04	23.49	23.67
WHC	g kg^{-1}	3.99	1.79	2.57	2.44	1.54	2.19
	% in TOC	7.81	13.58	17.02	19.31	16.84	10.44
NHC	g kg^{-1}	35.16	8.03	9.61	7.17	5.17	13.85
	% in TOC	68.11	60.71	59.09	56.08	55.98	64.01

Table 3

The content of nitrogen forms in soil under different land use

Carbon form		BOF	M	AF	F	SAB	SAA
NO_3-N	g kg^{-1}	0.005	0.003	0.008	0.004	0.005	0.011
	% in TN	0.17	0.30	0.68	0.35	0.56	0.70
NH_4-N	g kg^{-1}	0.048	0.034	0.020	0.044	0.047	0.038
	% in TN	1.77	3.06	1.62	3.91	5.78	2.47
DON	g kg^{-1}	0.047	0.024	0.044	0.015	0.024	0.034
	% in TN	1.55	2.09	3.60	1.63	2.85	2.13
EHN	g kg^{-1}	0.874	0.339	0.338	0.383	0.280	0.436
	% in TN	29.72	30.23	27.40	34.27	34.26	27.44
WHN	g kg^{-1}	0.911	0.370	0.413	0.348	0.184	0.542
	% in TN	30.41	32.90	33.84	31.36	22.69	34.32
NHN	g kg^{-1}	1.161	0.353	0.397	0.330	0.285	0.534
	% in TN	36.38	31.42	32.88	28.75	33.86	32.94

Table 4

Values of the DOC:DON, EHC:EHN, WHC:WHN and NHC:NHN ratios

Ratio	BOF	M	AF	F	SAB	SAA
DOC:DON	16.6	18.6	7.5	19.2	18.2	11.7
EHC:EHN	12.9	9.1	10.6	7.4	7.7	11.5
WHC:WHN	4.4	4.9	6.4	7.0	8.3	4.1
NHC:NHN	33.0	23.6	25.2	24.4	19.4	28.0

play an important role in the functioning of natural and modified ecosystems. Mobile in soils, they are a carrier of nutrients and energy compounds (QUALLS, HAINES 1991), at the same time playing an important role in some pedogenetic processes (HAYES, MOORE 1992, JONCZAK 2012). The sizes of DOC pools and their contribution to the total soil carbon pool vary among different ecosystems (Hu et al. 1997). The intensity of DOC production and leaching is strongly affected by soil temperature and moisture (Christ, David 1996), and in forest ecosystems by tree species composition and its age (Remeš, Kulhavý 2009, Jonczak, Parzych 2012). In the studied soils, the highest content of DOC was observed in BOF stand (0.71 g kg^{-1}) , where it was significantly higher than the one observed in remaining stands (0.33-0.40 g kg^{-1}) – Tables 2, 5. The distribution of DOC in BOF, SAB and SAA stands has been, in general, consistent with the data presented by Remeš and Kulhavý (2009), who observed the influence of tree-stand age on the concentration of DOC in lysimetric waters.

Large differences between the stands were observed in the content of EHC – from 2.17 g kg^{-1} in SAB stand to 11.33 g kg^{-1} in BOF stand, but the contribution of EHC in TOC was comparable in each stand (21.81-23.67%) and with the data of Becher and Kalembasa (2011), who observed 16.9-30.6% in arable Cambisols and Luvisols of Siedlce Upland. WHC contributed be-

Table 5

Statistical significance of differences between the soils in the content of different forms of carbon and nitrogen and C:N ratios

Specification	BOF vs M	BOF vs AF	BOF vs F	BOF vs SAB	BOF vs SAA	M vs AF	M vs F	M vs SAB	M vs SAA	AF vs F	AF vs SAB	AF vs SAA	F vs SAB	F vs SAA	SAB vs SAA
DOC	++	++	++	++	++	-	-	-	-	-	-	-	-	-	-
EHC	++	++	++	++	++	-	-	++	++	+	++	++	+	++	++
WHC	++	+	++	++	++	++	++	-	+	-	++	-	++	-	+
NHC	++	++	++	++	++	-	+	++	++	+	++	+	++	++	++
TOC	++	++	++	++	++	+	-	++	++	+	++	+	++	++	++
NO_3-N	++	-	+	-	++	+	-	++	++	+	-	-	+	++	++
NH_4-N	-	++	-	-	-	++	+	++	-	++	++	++	-	+	++
DON	+	-	++	+	-	+	-	-	-	++	++	+	-	++	-
EHN	++	++	++	++	++	-	-	+	+	-	-	+	++	-	++
WHN	++	++	++	++	++	-	-	++	++	+	++	+	++	++	++
NHN	++	++	++	++	+	-	-	-	+	-	+	-	-	+	+
TN	++	++	++	++	++	+	-	++	++	-	++	+	++	++	++
DOC:DON	-	++	-	-	-	+	-	-	-	+	+	++	-	-	-
EHC:EHN	++	+	++	++	+	-	+	+	++	++	++	-	-	++	++
WHC:WHN	-	+	++	++	-	-	+	++	+	-	-	+	+	++	++
NHC:NHN	+	-	-	++	-	-	-	-	-	-	-	-	-	-	-
TOC:TN	++	++	++	++	++	-	-	-	+	+	+	-	-	+	+

++ differences statistically significant at $p<0.01$; + differences statistically significant at $p<0.05$;
- differences not significant statistically

tween 7.81-19.31% in TOC with concentrations from 1.54-3.99 g kg^{-1}. The above values were slightly lower than those quoted by Becher and Kalembasa (2011).

In each stand, the main form of carbon was NHC (55.98-68.11% in TOC), whose concentration was 5.17-35.16 g kg^{-1}. In most cases, the differences in the content of EHC, WHC, NHC and TOC observed between the stands were statistically significant (Table 5). In general, the highest content of TOC, as well as its different forms, was observed in BOF stand. However, the percentage of DOC in TOC was the lowest in BOF stand and the highest in SAB stand. Moreover, the lowest contribution of WHC and the highest of NHC were observed in BOF stand. The contribution of EHC in TOC was comparable in every stand and ranged from 21.81 to 23.67%. The content of each studied form of carbon was positively related to the content of SOM and TOC:TN ratio and negatively to volumetric density and pH (Table 6).

The content of NO_3-N was very small in the studied soils and ranged from 0.003 to 0.011 g kg^{-1} (0.17-0.70% in TN) – Table 3. The highest concentrations were observed in SAA and AF stands and the lowest in M stand. Low pH, as a limiting factor for nitrification, is probably the reason of the observed low concentrations of nitrates. The content of NO_3-N was negatively related to volumetric density, which is overall consistent with the data quoted by Haunz et al. (1992). The differences in NO_3-N concentrations observed between the stands could be partially a result of different intensity of nitrogen leaching in the soils with different compaction and under different uses (Shipitalo, Edwards 1993). The content of NH_4-N was higher than NO_3-N, and ranged from 0.020 g kg^{-1} in AF stand to 0.048 g kg^{-1} in BOF stand, being comparable to the one observed by Becher, Kalembasa (2011) of 0.017-0.039 g kg^{-1}. The contribution of NH_4-N form in TN ranged from 1.62 to 5.78%. DON contributed in TN in 1.55-3.60% with concentrations 0.015-0.047 g kg^{-1}.

Hydrolyzable and nonhydrolyzable forms always predominate in the soil total nitrogen, but proportions between the forms are varied in different soil types and under different uses (eg. Hersemann 1987, Sharpley, Smith 1995, Sulce et al 1996). EHN, WHN and NHN were also the main forms of nitrogen in the investigated soils. There were no large differences between the stands in contribution of the forms in TN. Such regularities were also

Table 6

Correlation coefficients between the content (g kg^{-1}) of carbon and nitrogen forms and some properties of the soils

Specification	DOC	EHC	WHC	NHC	NO_3-N	NH_4-N	DON	EHN	WHN	NHN
Volumetric density	**-0.782***	**-0.871**	**-0.621**	**-0.842**	**-0.381**	-0.067	-0.340	**-0.868**	**-0.825**	**-0.785**
pH	**-0.645**	**-0.691**	**-0.450**	**-0.658**	**-0.424**	-0.348	**-0.373**	**-0.649**	**-0.617**	**-0.615**
SOM	**0.888**	**0.978**	**0.886**	**0.987**	0.098	0.110	**0.648**	**0.948**	**0.951**	**0.949**
TOC:TN	**0.738**	**0.869**	**0.644**	**0.858**	0.117	0.162	**0.571**	**0.863**	**0.840**	**0.660**

* in bold – correlations statistically significant at $p<0.05$

observed by Becher and Kalembasa (2011) in arable Cabbisols and Luvisols, and by the same authors in peat-muck soils (Kalembasa, Becher 2009), as well as by Czekała (2010) in Luvisols under different uses. The contribution of EHN in TN was 27.40-34.27%, and WHN – 22.69-34.32%. These percentages of NHN (28.75-36.38%) were comparable to the ones observed by Sulce et al. (1996) in Cambisols (34.5%), as well as by Sharpley and Smith (1995) in different soil types (30.4-34.8%). The content of organic forms of nitrogen (DON, EHN, WHN and NHN) in the investigated soils was positively correlated to the content of SOM and TOC:TN ratio, and negatively to the volumetric density and soil pH (Table 6).

The C:N ratio is a good parameter in the assessment of the impact of different factors on soil's biological activity and the intensity of nutrient cycling (Gundersen et al. 1998, Smolander, Kitunen 2002, Akselsson et al. 2005, Vesterdal et al. 2008). The lowest DOC:DON ratio was observed in AF stand (7.5:1) and a slightly higher in SAA stand (11.7:1). In the remaining stands, the ratios were 16.6:1-18.6:1. High differences were observed between the stands in the DOC:DON ratio (7.5:1-18.6:1), which indicates varied biological activity of the investigated soils. The observed EHC:EHN ratios (7.4:1 to 12.9:1) were comparable or slightly higher than the ones given by Becher and Kalembasa (2011). The lowest values of the C:N ratio were observed in the weakly hydrolyzing (4.1:1-8.3:1) and the highest ones - in the nonhydrolyzable fraction (19.4:1-33.0:1). The lowest C:N ratios observed in the weakly hydrolyzing fraction could be a result of the hydrolysis of bodies of microorganisms, relatively resistant to reagents, which accumulate a significant share of soil nitrogen. Most nitrogen was released after extraction with 2.5 mol H_2SO_4 dm^{-3}.

CONCLUSIONS

Different land uses were significantly reflected in the properties of the A horrizon of the investigated Stagnic Luvisols. Particularly high differences were observed between the forest soils, never used for agriculture, and the arable or post-arable soils. Tillage caused the increase of the A horizon depth from 9.2 to 26.4-35.6 cm, which was a result of the mixing of the primary A horizon with E horizon, and the increase of its volumetric density. The highest content of SOM, TOC and TN as well as the TOC:TN ratio were observed in forest soils.

Statistically significant differences between the stands in the content of different forms of carbon were identified in most cases. The content of every form was positively correlated with the content of SOM and the TOC:TN ratio, but negatively with volumetric density and pH. The nonhydrolyzable form of carbon dominated in the soils (55.98-68.11% of TOC), and DOC had the lowest contribution (1.43-3.70% in TOC). In general, higher contribution of DOC in TOC was observed in arable and post-arable soils in relation to forest soils. The observed content and contributions of different forms of carbon in TOC were comparable to the ones observed by other authors in similar soil types.

The content of mineral nitrogen (NO_3-N + NH_4-N) ranged from 0.028 to 0.053 g kg^{-1}, and NH_4-N dominated in the pool. The lowest concentration of mineral nitrogen was observed in arable soils, and significantly higher in forest and fallow soils. EHN, WHN and NHN were the main forms of nitrogen. As the content of the forms was positively correlated to the content of SOM, their highest concentration was observed in BOF stand.

The differences in the DOC:DON, EHC:EHN, WHC:WHN and NHC: NHN ratios observed between the stands suggest varied biological activity of the soil under different uses. The lowest C:N ratio values were observed in the weakly hydrolyzable (4.1:1-8.3:1) and the highest – in the nonhydrolyzable fraction (19.4:1-33.0:1).

REFERENCES

Akselsson C., Berg B., Meentemeyer V., Westling O. 2005. *Carbon sequestration rates in organic layers of boreal and temperate forest soils - Sweden as a case study*. Global Ecol. Biogeogr., 14: 77-84.

Anderson S., Nilsson S.I., Saetre P. 2002. *Leaching of dissolved organic carbon (DOC) and dissolved organic nitrogen (DON) in mor humus as affected by temperature and pH*. Soil Biol.Biochem., 32: 1-10.

Becher M., Kalembasa D. 2011. *Fractions of nitrogen and carbon in humus horizons of arable Luvisols and Cambisols located on Siedlce upland*. Acta Agroph., 18(1): 7-16. (in Polish)

Bejger R., Gołębiowska D. 2005. *Comparison of physico-chemical and humic acids optical parameters of four peat species*. Humic Substances Ecosystems, 6: 13-16.

Chertov O.G., Komarov A.S. 1997. *SOMM: A model of soil organic matter dynamics*. Ecol. Model., 94: 177-189.

Cheshire M.V., Russell J.D., Fraser A.R., Bracewell J.M., Robertson G.W., Benzing-Purdie L.M., Ratcliffe C.I., Ripmeester J.A., Goodman B.A. 1992. *Nature of soil carbohydrate and its association with soil humic substances.* J. Soil Sci., 43: 359-373.

Christ M.J., David M.B. 1996. *Temperature and moisture effects on the production of dissolved organic carbon in a spodosol*. Soil Biol. Biochem., 28(9): 1191-1199.

Cotrufo M.F., De Santo A.V., Alfani A., Bartoli G., De Cristofaro A. 1995. *Effects of urban heavy metal pollution on organic matter decomposition in Quercus ilex* L. *woods*. Environ. Pollut., 89: 81-87.

Czekała J. 2010. *Impact of long-term plant cultivation without participation of cereals on concentrations of nitrogen forms in soil humus horizon*. J. Res. Appl. Agric. Eng., 55(3): 49-53.

Dawson J.J.C., Soulsby C., Tetzlaff D., Hrachowitz M., Dunn S.M., Malcolm I.A. 2008. *Influence of hydrology and seasonality on DOC exports from three contrasting upland catchments*. Biogeochemistry, 90: 93-113.

Domagała-Świątkiewicz I., Sady W. 2011. *Effect of nitrogen fertilization on P, K, Mg, Ca and S content in soil and edible parts of white cabbage*. J. Elem., 16(2): 177-193. DOI: 10.5601/jelem.2011.16

Dziadowiec H., Lutowska M. 2005. *The effect of ants Formica polyctena trail system on the organic matter transformation*. Humic Substances Ecosystems, 6: 41-46.

DZIAMSKI A., GONET S.S., DĘBSKA B. 2005. *Effects of organic fertilization on the parameters of thermal decomposition of humic acids.* Humic Substances in Ecosystems 6: 46-51.

FRÖBERG M., KLEJA D.B., BERGKVIST B., TIPPING E., MULDER J. 2005. *Dissolved organic carbon leaching from a coniferous forest floor – a field manipulation experiment.* Biogeochemistry, 75: 271-281.

GONDEK K. 2007. *Content of carbon, nitrogen and selected heavy metals in composts.* J. Elementol., 12(1): 13-23.

GONET S.S., DĘBSKA B. 2007. *Qualitative parameters of organic matter in the Ol sub-horizons of forest soils.* Humic Substances Environment, 7: 129-141.

GUNDERSEN P., CALLESEN I., DE VRIES W. 1998. *Nitrate leaching in forest ecosystems is related to forest floor C/N ratios.* Environ. Pollut., 102: 403-407.

HAUNZ F.X., MAIDL F.X., FISCHBECK G. 1992. *Effect of soil compaction on the dynamics of soil and fertilizer nitrogen under winter wheat.* Zl Pflanzenernachr. Bodenkd., 155: 129-134. (in German)

HERSEMANN H. 1987. *Veranderungen der Art und Menge der organischen Substanz in der Ackerkrume von Langzeit-Feldversuchen, gemessen an einigen chemischen und physikalischen Parametern.* Gött Bodenkdl Ber, 92: 1-100. (in German)

HEYES, A., MOORE, T.R. 1992. *The influence of dissolved organic carbon and anaerobic conditions of mineral weathering.* Soil Sci., 154: 226-236.

HU S., COLEMAN D.C., CARROLL C.R., HENDRIX P.F., BEARE M.H. 1997. *Labile soil carbon pools in subtropical forest and agricultural ecosystems as influenced by management practices and vegetation types.* Agric., Ecosyst. Environ., 65: 69-78.

HUE, N.V., CRADDOCK, G.R., ADAMS, F. 1986. *Effect of organic acids on aluminum toxicity in subsoils.* Soil Sci. Soc. Am. J., 50: 28-34.

JONCZAK J. 2012. *The effect of pine and spruce admixture in a beech stand on the intensity of carbon, iron and aluminum leaching from humic and organic horizons of Dystric Arenosols in northern Poland.* Forest Res. Papers, 73(2): 143-151. (in Polish)

JONCZAK J., PARZYCH A., 2012. *Impact of Scots pine admixture in European beech stand on dissolved organic carbon and nitrogen leaching from organic and humic horizons of Dystric Arenosols in northern Poland.* J. Forest Sci., 58(6): 278-286.

KALEMBASA D., BECHER M. 2009. *Fractions of nitrogen in drained peat-muck soils located in the upper Liwiec River valley.* Water-Environment-Rural Areas, 9(2): 73-82. (in Polish)

KALEMBASA D., BECHER M. 2012. *Speciation of carbon and selected metals in spent mushroom substrates*, J. Elem., 17(3): 409-419. DOI: 10561/jelem.2012.17.3

KLIMOWICZ Z., UZIAK S., 2001. *The influence of long-term cultivation on soil properties and patterns in an undulating terrain in Poland.* Catena, 43: 177-189.

KUŽEL S., KOLÁŘ L., LEDVINA R., SPALEVIČ V. 2001. *Transformation of organic matter in mountain and submountain regions of* Šumava *in comparison with* České *Budějovice Basin.* Humic Substances Ecosystems, 4: 79-85.

KWIATKOWSKA J., MACIEJEWSKA A. 2003. *Fractional composition of humic acids and some physico-chemical properties of soil as a result of addition a brown coal fertilizer.* Humic Substances Environment, 5: 57-77.

ŁABAZ B., GLINA B., BOGACZ A. 2011. *Properties of humus substances in differently used soils of the Milicz-Głogów depression.* Pol. J. Soil Sci., 44(2): 177-192.

LAIK R., KUMAR K., DAS D.K., CHATURVEDI O.P. 2009. *Labile soil organic matter pools in a calciorthent after 18 years of afforestation by different plantations.* Appl. Soil Ecol., 42: 71-78.

LIPIEC J., STĘPNIEWSKI W. 1995. *Effects of soil compaction and tillage systems on uptake and losses of nutrients.* Soil Tillage Res., 35: 37-52.

MANDER U., KULL A., KUUSEMETS V., TAMM T. 2000. *Nutrient runoff dynamics in a rural catchment: Influence of land-use changes, climatic fluctuations and ecotechnological measures.* Ecol. Eng., 14: 405-417.

MURPHY D.V., MACDONALD A.J., STOKDALE E.A., GOULDING K.W.T., FORTUNE S., GAUNT J.L., POLUTON P.R., WAKEFIELD J.A., WEBSTER C.P., WILMER W.S. 2000. *Soluble organic nitrogen in agricultural soils*. Biol. Fertil. Soils, 30: 374-387.

NIEDER R., RICHTER J. 2000. *C and N accumulation in arable soils of West Germany and its influence on the environment – Developments 1970 to 1998.* J. Plant Nutr. Soil Sci., 163: 65-72.

PULLEMAN M.M., BOUMA J., VAN ESSEN E.A., MEIJLES E.W. 2000. *Soil organic matter content as a function of different land use history*. Soil Sci. Soc. Am. J., 64: 689–693.

QUALLS, R.G., HAINES, B.L. 1991. *Geochemistry of dissolved organic nutrients in water percolating through a forest ecosystem*. Soil Sci. Soc. Am. J., 55: 1112-1123.

REMEŠ M., KULHAVÝ J. 2009. *Dissolved organic carbon concentrations under conditions of different forest composition.* J. Forest Sci., 55(5): 201-207.

SCHMITT A., GLASER B. 2011. *Organic matter dynamics in a temperate forest as influenced by soil frost.* J. Plant Nutrit. Soil Sci., 174: 754-764.

SHARPLEY A.N., SMITH S.J. 1995. *Nitrogen and phosphorus in soils receiving manure.* Soil Sci., 159: 253-258.

SHIPITALO M.J., EDWARDS W.M. 1993. *Seasonal patterns of water and chemical movement in tilled and no-till column lysimeters.* Soil. Sci. Soc. Am. J., 57: 218-223.

SIENKIEWICZ S., WOJNOWSKA T., KRZEBIETKE S., WIERZBOWSKA T., ŻARCZYŃSKI P. 2009. *Content of available forms of some micronutrients in soil after long-term differentiated fertilization.* J. Elem., 14(4): 787-794. DOI: 10.5601/jelem.2009.14.4

SIMANSKY V. 2007. *Influence of different tillage systems on quantity and quality of soil organic matter in Haplic Luvisols under sugar beet farming system.* Humic Substances Ecosystems, 7: 57-61.

SMOLANDER A., KITUNEN V. 2002. *Soil microbal activities and characteristics of dissolved organic C and N in relation to tree species*. Soil Biol. Biochem., 34: 651-660.

SULCE S., PALMA-LOPEZ D., JAQUIN F., VONG P.C., GUIRAUD G. 1996. *Study of immobilization and remobilization of nitrogen fertilizer in cultivated soils by hydrolytic fractionation.* Eur. J. Soil Sci., 47: 249-255.

SZOMBATHOVA N., CHLPIK J., SIMANSKY V. 2005. *Soil organic matter as an indicator of soil genesis.* Humic Substances Ecosystems, 6: 176-181.

TOBIASOVA E., KRAJCOVICOVA D., CERVENKA J., SZOMBATHOVA N. 2005. *Quality and quantity of soil organic matter under different tree species in forest and town.* Humic Substances Ecosystems, 6: 190-193.

VESTERDAL L., SCHMIDT I.K., CALLESEN I., NILSSON L.O., GUNDERSEN P. 2008. *Carbon and nitrogen in forest floor and mineral soil under six common European tree species*. Forest Ecol. Manage., 255: 35-48.