J. Elem. s. 95–105

DOI: 10.5601/jelem.2014.19.4.398

DISTRIBUTION OF CARBON AND NITROGEN FORMS IN HISTOSOLS OF HEADWATER AREAS – A CASE STUDY FROM THE VALLEY OF THE KAMIENNA CREEK (NORTHERN POLAND)

Jerzy Jonczak*, **Agnieszka Parzych**[2], **Zbigniew Sobisz**[3]

[1]**Departament of Geoecology and Geoinformation**
[2]**Department of Environmental Chemistry**
[3]**Department of Botany and Environmental Protection**
Pomeranian University in Słupsk

Abstract

The aim of the study was to recognize the vertical variability in the content of different forms of carbon and nitrogen in Histosols of a forest spring niche located in the upper course of the Kamienna Creek (the Słupia River catchment). Soil samples were taken from three profiles and analyzed with standard methods used in the soil science. Analyses included the degree of peat mass decomposition, content of soil organic matter, pH, content of total organic carbon (TOC), total nitrogen (TN) and forms of carbon and nitrogen 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}. The following fractions were isolated: nonhydrolyzable carbon (NHC) and nitrogen (NHN), weakly hydrolyzable carbon (WHC) and nitrogen (WHN), easy hydrolyzable carbon (EHC) and nitrogen (EHN), dissolved organic nitrogen (DON), and its ammonium (NH_4-N) and nitrate (NO_3-N) form.

The Histosols were t up to 0.9 m hick. The degree of peat mass decomposition was 3-9. The content of organic matter ranged from 317.3 to 829.0 g kg^{-1}, and TOC from 162.2 to 459.5 g kg^{-1}. The soils were acid at pH_{H2O} equal 5.6-6.5. The NHC form predominated in TOC. The content of the form was 117.3-399.7 g kg^{-1}, and contribution in TOC 72.3-89.2%. Soils contained 17.1-41.7 g kg^{-1} of WHC (4.5-10.6% in TOC), and 27.3-62.2 g kg^{-1} EHC (6.4-17.2% in TOC). The soils were rich in total nitrogen (TN), whose content was 11.1-33.6 g kg^{-1}. The content of NHN was 5.50-18.89 g kg^{-1} (37.18-69.84% in TN), WHN 4.28-14.17 g kg^{-1} (21.23-43.72 in TN), EHN 1.16-8.02 g kg^{-1} (8.06-24.32% in TN), and DON ranged from 0.029-0.394 g kg^{-1} (0.10-1.20% in TN). The concentration of NH_4-N was 0.043-0.337 g kg^{-1}, and NO_3-N 0.003-0.012 g kg^{-1}. Similar regularities in the vertical distribution of the investigated forms of carbon and nitrogen were observed in every soil profile. In general, an increase in the nonhydrolyzable forms of carbon and nitrogen and a decrease in EHC, EHN, DON and NH_4-N were observed with depth. The maximum concentration of EHC, EHN, DON and NH_4-N found in bog horizons is probably an

Jerzy Jonczak, Departament of Geoecology and Geoinformation Pomeranian University in Słupsk, Partyzantów 27, 76-200 Słupsk, Poland, e-mail: jrzy.jonczak@gmail.com

effect of the highest intensity of biochemical processes in the topsoil and the influx of fresh litterfall. A constant underground flow of water and leaching are the factors which caused a low contribution of labile forms of C and N in lower parts of the soil profiles.

Key words: headwater areas, Histosols, carbon forms, nitrogen forms.

INTRODUCTION

Headwater areas, as transition zones between underground and superficial parts of a water cycle in river catchments, play an important role in the functioning of geosystems (Chapman et al 1993, Mazurek 2006, Jekatierynczuk-Rudczyk 2007, Jonczak 2011). Water, soil and plant communities play the key role in the functioning of spring niches, and interactions between these components are very close and anisotropic (Devito et al 1996, Foster et al 2001, Davies et al 2005, Karlsson et al 2005, Szymczyk et al 2010, Daniels et al 2012, Mazurek 2012). The water outflow rate affects the degree of swamping in the vicinity of water seepages, while its chemical composition has a strong impact on species-composition of plant communities. Plants are a source of litterfall, whose accumulation under the lasting surplus of water leads to the formation of Histosols. Physical and chemical properties of soils are conditioned by the character of past and contemporary plant communities and the chemistry of supplying water. On the other hand, the soils influence the direction and range of transformations in water chemistry during the flow through a niche (Jekatierynczuk-Rudczyk 2007, Mazurek 2012). The soils of spring niches are usually rich in organic matter, which affects their physical, chemical, sorptive and buffer properties (Jonczak 2010, Jonczak, Cysewska 2010). Soil organic matter (SOM) is present in the soils in different forms – from fresh litterfall, through humus to soluble (labile) organic compounds. Litterfall is a primary source of SOM, and dissolved organic matter (DOM) is a product of its microbiological decomposition and a substrate in humification process. Thus, the content of different forms of SOM resulted from the rate of microbiological decomposition of litterfall, humification and leaching, which in turn was strongly affected by soil properties and many environmental and anthropogenic factors. Carbon and nitrogen (beside oxygen and hydrogen) are major components of SOM. Bearing in mind permanent flow of water through Histosols of headwater areas, especially in horizons over mineral bed, we should expect in general low, but vertically differentiated content of labile forms of carbon and nitrogen.

The aim of our study was to recognize the vertical variability in the content of different forms of carbon and nitrogen in Histosols of forest spring niche located in the upper course of Kamienna Creek.

MATERIAL AND METHODS

The studies were conducted in northern Poland, in the valley of the Kamienna Creek – a left tributary of the Słupia River. The Kamienna Creek valley is a deep headwater area, carved in the Holocene sands and loams and rich in water seepages and spring niches, which are the subject of our studies. This paper presents results of the studies conducted in an afforested spring niche located in the upper course of the river, near Łysomice (54°19′ N; 17°10′ E). This spring niche is a riparian area overgrown with 40-86 years-old alder trees (*Alnus glutinosa*) and having a very species rich herbaceous plant cover. iIn total, there were 106 species of vascular plants, 17 species of mosses and 8 species of liverworts identified in the niche in 2012. This is a lowland peatbog area with Histosols of the thickness to about 90 cm. In the summer of 2012, three soil profiles were uncovered, in which the soils described and sampled. Soil samples were taken from 10 cm layers, up to the mineral bed. The degree of peat mass decomposition (H) was determined in field on the von Post's scale (Grosse-Brauckmann 1990). Soil samples were dried at 40°C, ground and analyzed. The following properties were analyzed:

- pH potentiometrically (Elmetron CP-401) in H_2O and 1mol dm^{-3} KCl (in the soil:water/KCl ratio of 1:10);
- soil organic matter (SOM) content as loss on ignition at 450°C;
- total organic carbon (TOC) content with the Alten method;
- total nitrogen (TN) content with the Kjeldahl method in a distilling unit VELP UDK-127;
- 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:

- 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- 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 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 calculated as TN-NH_4-N–DON–EHN-WHN.

The content of carbon in extracts was analyzed with the Tiurin method after evaporation of a sample, NO_3-N was determined colorimetrically with sodium salicylate, NH_4-N was assayed by distillation and organic nitrogen was tested by the Kjeldahl method in a distilling unit VELP UDK-127. Correlation coefficients between the content of carbon and nitrogen forms and some properties of the soils were calculated using Statistica software.

RESULTS AND DISCUSSION

The surplus of water, which is typical for headwater areas, creates conditions for the development of Histosols. The tickness of soils is determined mainly by the basic microrelief in the vicinity of water seepages and the species composition of plant communities. The Histosols subjected to our investigations were thick up to 90 cm and built from alder-sedge peat, whose rate of decomposition on the von Post's scale (Grosse-Brauckmann 1990) was 3-9 (Table 1). The soils contained 317.3-829.0 g kg^{-1} of SOM, 162.2-459.5 g kg^{-1} TOC and 11.08-33.59 g kg^{-1} TN. The TOC:TN ratio ranged from 12.6:1 to 22.0:1. The soils were acid at pH_{H2O} from 5.6 to 6.5 and pH_{KCl} from 5.0 to 6.1.

It is well known that labile forms of SOM, carbon and nitrogen play an important role in the functioning of natural and modified ecosystems, as well as in some soil-forming processes (e.g. Qualls, Haines 1991, Hayes, Moore 1992, Schulten, Schnitzer 1998, Jonczak 2012). Concentrations and pools of the forms in soils are varied among different ecosystems (Hu et al. 1997). Decaying litterfall in forest and other natural ecosystems, and some organic fertilizers in agroecosystems (Gondek 2007, Kalembasa, Beher 2012) are the most important sources of the components in the environment. The content of dissolved organic carbon (DOC), as well as its leaching intensity is a good indicator of the ecological condition of soils and the direction of ongoing processes as a response to the impact of different environmental and anthropogenic factors (Hu et al. 1997, Chertov, Komarov 1997, Dawson et al. 2008, Remeš, Kulhavý 2009, Jonczak, Parzych 2012). The investigated Histosols were rich in SOM, acting as substrate for labile forms of carbon, but the constant water surplus did not favour its mineralization. Finally, the observed concentrations of EHC were rather low, ranging from 27.3 to 62.2 g kg^{-1} (Table 2). EHC accounted 6.4-17.2% of TOC. In general, the highest concentration as well as the contribution of this form in TOC occurred in the 0-30 cm layer, while the lowest ones were in layers lying on the mineral bed. The observed vertical distribution of EHC is an effect of the varied biological activity in soil profiles (which peaked in bog horizons) and the intensive leaching of labile forms from the zones with a constant flow of groundwater. The content of WHC ranged from 17.1 to 41.7 g kg^{-1} (4.5-10.6% of TOC). NHC was the major fraction of carbon in the investigated soils, with concentrations from 117.3 to 399.7 g kg^{-1} and contribution in TOC equal

Table 1

Selected properties of the soils

Depth (cm)	H von Post	SOM (g kg^{-1})	TOC (g kg^{-1})	TN (g kg^{-1})	TOC:TN	pH_{H_2O}	pH_{KCl}
Profile 1							
0-10	9	725.0	421.9	33.0	12.8	6.1	5.5
10-20	9	741.0	423.4	33.6	12.6	6.0	5.4
20-30	9	753.0	443.5	32.4	13.7	5.8	5.3
30-40	5	705.9	438.9	30.1	14.6	5.8	5.3
40-50	5	611.8	384.2	26.3	14.6	5.9	5.4
50-60	6	538.0	325.7	21.8	15.0	5.6	5.3
Profile 2							
0-10	9	810.8	436.6	32.9	13.3	6.5	6.0
10-20	5	803.8	422.2	32.0	13.2	6.4	5.8
20-30	3	813.5	459.5	30.5	15.1	6.5	6.1
30-40	7	795.4	448.1	29.7	15.1	6.5	6.0
40-50	6	721.6	451.2	30.8	14.7	6.4	5.9
50-60	9	633.3	379.1	25.9	14.6	6.5	6.0
60-70	6	678.3	458.7	27.8	16.5	5.9	5.6
70-80	5	620.1	427.8	19.5	22.0	5.6	5.3
80-90	4	634.6	425.3	21.5	19.8	5.6	5.4
Profile 3							
0-10	9	805.2	443.7	29.7	15.1	5.9	5.2
10-20	8	829.0	447.8	29.3	15.2	5.6	5.0
20-30	8	794.6	442.4	33.2	13.2	5.6	5.1
30-40	8	721.8	411.7	28.6	14.4	5.9	5.2
40-50	9	734.7	389.2	29.3	13.3	5.8	5.2
50-60	8	735.6	394.2	31.1	12.7	5.8	5.4
60-70	7	588.6	356.8	19.8	17.6	5.9	5.5
70-80	7	413.7	240.6	13.1	17.6	6.0	5.6
80-90	9	317.3	162.2	11.1	13.5	5.9	5.5

72.3-89.2% (Table 2). The concentrations of EHC, WHC and NHC were closely related to the content of SOM (Table 3).

Almost all of the nitrogen contained in soils is closely associated with SOM. It is present in soils as a component of different organic compounds and in mineral forms - ammonium, nitrates and nitrites. Mineral nitrogen usually constitutes a fraction of percent in total nitrogen, but as a bioavailable form of the element, it plays the key role in the functioning of plant

Table 2

The content of carbon forms in the soils and their contribution in TOC

Depth (cm)	Content ($g\ kg^{-1}$)			Contribution in TOC (%)		
	EHC	WHC	NHC	EHC	WHC	NHC
Profile 1						
0-10	60.5	35.2	326.2	14.3	8.3	77.4
10-20	62.2	30.3	330.9	14.7	7.2	78.1
20-30	49.7	34.7	359.1	11.2	7.8	81.0
30-40	41.3	34.4	363.2	9.4	7.8	82.8
40-50	33.6	22.4	328.2	8.8	5.8	85.4
50-60	33.5	22.0	270.2	10.3	6.8	82.9
Profile 2						
0-10	50.5	36.2	349.9	11.6	8.3	80.1
10-20	50.6	31.8	339.8	12.0	7.5	80.5
20-30	51.4	33.1	375.0	11.2	7.2	81.6
30-40	43.0	34.7	370.4	9.6	7.7	82.7
40-50	40.9	31.2	379.2	9.1	6.9	84.0
50-60	33.2	29.0	316.9	8.8	7.6	83.6
60-70	31.5	27.5	399.7	6.9	6.0	87.1
70-80	27.3	19.1	381.5	6.4	4.5	89.2
80-90	27.8	20.4	377.1	6.5	4.8	88.7
Profile 3						
0-10	50.5	36.5	356.7	11.4	8.2	80.4
10-20	50.6	38.7	358.5	11.3	8.6	80.1
20-30	51.4	37.9	353.1	11.6	8.6	79.8
30-40	43.0	34.3	334.5	10.4	8.3	81.2
40-50	40.9	35.1	313.2	10.5	9.0	80.5
50-60	33.2	41.7	319.2	8.4	10.6	81.0
60-70	31.5	28.7	296.5	8.8	8.1	83.1
70-80	27.3	22.9	190.4	11.3	9.5	79.1
80-90	27.8	17.1	117.3	17.2	10.6	72.3

communities and soil microorganisms. It is also a limiting factor in this respect. Mineral forms of nitrogen, especially NO_3-N, are highly mobile in the environment, which is a frequent reason of water pollution in agroecosystems. A lower rate of the mineralization of organic nitrogen due to water excess, uptake by plant roots and microorganisms as well as intensive leaching is the most decisive factor causing a very low concentration of NO_3-N in the studied soils, despite the high content of TN. The content of the form ranged from 0.003 to 0.012 $g\ kg^{-1}$ (0.01-0.04% in TN). Low concentrations

Table 3

Correlation coefficients between the content (g kg^{-1}) of carbon and nitrogen forms and some properties of the soils (in bold correlations statistically significant at $p < 0.05$)

Specification	EHC	WHC	NHC	NO_3-N	NH_4-N	DON	EHN	WHN	NHN
SOM (%)	**0.727**	**0.813**	**0.810**	0.263	**0.535**	0.258	**0.671**	**0.713**	**0.860**
TOC (%)	**0.529**	**0.586**	**0.979**	0.260	0.388	0.204	**0.547**	**0.554**	**0.875**
TN (%)	**0.794**	**0.810**	**0.706**	0.299	**0.673**	0.344	**0.843**	**0.868**	**0.801**
TOC:TN	**-0.611**	**-0.584**	0.146	-0.033	**-0.570**	-0.219	**-0.671**	**-0.714**	-0.185
pH_{H2O}	0.272	0.190	0.088	0.294	0.280	0.288	0.215	0.303	0.169
H	0.292	0.290	0.297	0.276	0.328	0.188	**0.475**	**0.505**	0.225

Table 4

The content of nitrogen forms in the soils and their contribution in TN

Depth (cm)	Content (g kg^{-1})						Contribution in TN (%)					
	NO_3-N	NH_4-N	DON	EHN	WHN	NHN	NO_3-N	NH_4-N	DON	EHN	WHN	NHN
Profile 1												
0-10	0.011	0.337	0.394	8.02	11.31	12.91	0.03	1.02	1.20	24.32	34.30	39.13
10-20	0.008	0.246	0.267	7.94	11.28	13.85	0.02	0.73	0.80	23.63	33.59	41.23
20-30	0.007	0.182	0.120	5.88	14.17	12.05	0.02	0.56	0.37	18.14	43.72	37.18
30-40	0.005	0.174	0.029	5.34	8.62	15.95	0.02	0.58	0.10	17.73	28.63	52.96
40-50	0.004	0.099	0.093	3.74	9.15	13.20	0.02	0.38	0.35	14.24	34.81	50.21
50-60	0.004	0.091	0.056	3.72	7.16	10.72	0.02	0.42	0.26	17.09	32.93	49.29
Profile 2												
0-10	0.012	0.305	0.269	5.25	11.81	15.29	0.04	0.93	0.82	15.93	35.87	46.42
10-20	0.008	0.189	0.190	5.06	9.69	16.81	0.03	0.59	0.60	15.82	30.34	52.63
20-30	0.005	0.149	0.127	4.44	9.42	16.37	0.02	0.49	0.42	14.55	30.88	53.65
30-40	0.004	0.104	0.085	3.97	9.23	16.35	0.02	0.35	0.29	13.34	31.04	54.97
40-50	0.006	0.110	0.105	4.22	9.28	17.06	0.02	0.36	0.34	13.72	30.14	55.42
50-60	0.007	0.081	0.099	3.69	8.20	13.87	0.03	0.31	0.38	14.22	31.61	53.46
60-70	0.004	0.085	0.167	2.99	7.42	17.13	0.02	0.30	0.60	10.76	26.68	61.64
70-80	0.008	0.043	0.149	1.63	4.60	13.06	0.04	0.22	0.76	8.35	23.63	67.00
80-90	0.008	0.067	0.112	1.73	4.57	15.02	0.04	0.31	0.52	8.06	21.23	69.84
Profile 3												
0-10	0.007	0.241	0.182	5.19	8.55	15.57	0.02	0.81	0.61	17.46	28.74	52.35
10-20	0.003	0.073	0.100	4.68	9.28	15.18	0.01	0.25	0.34	15.97	31.65	51.78
20-30	0.004	0.201	0.075	4.78	9.24	18.89	0.01	0.61	0.23	14.40	27.83	56.93
30-40	0.008	0.169	0.148	4.39	9.05	14.81	0.03	0.59	0.52	15.37	31.67	51.82
40-50	0.005	0.102	0.105	4.43	9.24	15.38	0.02	0.35	0.36	15.13	31.58	52.56
50-60	0.007	0.120	0.125	3.63	10.56	16.70	0.02	0.38	0.40	11.65	33.91	53.63
60-70	0.006	0.094	0.098	1.90	6.52	11.15	0.03	0.48	0.49	9.62	33.00	56.39
70-80	0.006	0.069	0.141	1.23	4.95	6.66	0.04	0.53	1.08	9.45	37.92	50.98
80-90	0.003	0.056	0.083	1.16	4.28	5.50	0.03	0.51	0.75	10.50	38.58	49.63

of the form of nitrogen were also observed by JONCZAK (2012) in the soils of spring niches in the Jarosławianka Creek valley (0.003-0.018 g kg^{-1}), and is probably a characteristic feature of soils of headwater areas. Much higher

Table 5

The values of EHC:EHN, WHC:WHN and NHC:NHN ratios

Depth (cm)	EHC:EHN	WHC:WHN	NHC:NHN
Profile 1			
0-10	6.9	3.1	25.3
10-20	7.4	2.7	23.9
20-30	8.0	2.4	29.8
30-40	7.4	4.0	22.8
40-50	8.5	2.4	24.9
50-60	8.7	3.1	25.2
Profile 2			
0-10	8.7	3.1	22.9
10-20	9.3	3.3	20.2
20-30	10.9	3.5	22.9
30-40	10.3	3.8	22.6
40-50	9.2	3.4	22.2
50-60	8.6	3.5	22.9
60-70	9.7	3.7	23.3
70-80	14.9	4.1	29.2
80-90	14.5	4.5	25.1
Profile 3			
0-10	9.9	4.3	22.9
10-20	10.1	4.2	23.6
20-30	9.4	4.1	18.7
30-40	9.1	3.8	22.6
40-50	9.1	3.8	20.4
50-60	9.0	4.0	19.1
60-70	10.8	4.4	26.6
70-80	11.7	4.6	28.6
80-90	11.4	4.0	21.3

concentrations were noticed by Kalembasa and Becher (2009) in peat-muck soils in the Liviec River valley (E Poland) – 0.053-0.090 g·kg^{-1}.

The content of NH_4-N in the studied soils was 0.043-0.337 g kg^{-1} (0.22-1.02% in TN) – Table 4. Both the content of NH_4-N and its contribution in TN were the highest in the surface horizons of the soils (0-10 cm) and decreased with depth. The observed concentrations of the form were higher than noticed by Kalembasa and Becher (2009), who noticed 0.137-0.200 g kg^{-1} in M_t horizons and 0.095-0.158 g kg^{-1} in O_{tni} horizons of peat-muck soils. DON is the most labile form, being also most susceptible to mineralization of organic nitrogen. In the analyzed soils, DON contributed 0.10-1.20% in TN, and its concentration ranged from 0.029 to 0.394 g kg^{-1}. The highest content of the form was observed in the surface layer.

The contribution of hydrolyzable forms of nitrogen to TN was 29.29-61.86%. WHN predominated in the pool, with the content 1.4-4.0-fold higher than EHN. The content of hydrolyzable forms of nitrogen decreased with depth. The content of EHN and WHN was significantly positively related to the content of SOM, TOC, TN and degree of the decomposition of peat mass, being negatively correlated to the TOC:TN ratio (Table 3). NHN contributed 37.18-69.84% to TN, with concentrations of 5.50-18.89 g kg^{-1}. The observed dominance of hydrolyzable and nonhydrolyzable forms in the pool of TN is consistent with the data of other authors (Hersemann 1987, Sharpley, Smith 1995, Sulce et al 1996 Kalembasa, Becher 2009, Becher, Kalembasa 2011). A specific feature of the investigated Histosols is a high dominance of nonhydrolyzable forms over hydrolyzable ones, which can be a result of intensive leaching of labile forms of elements by the permanent flow of groundwater.

The significant differences between EHC:EHN, WHC:WHN and NHC: NHN suggest variability in the content of nitrogen in fractions of organic compounds characterized by different susceptibility to hydrolysis. The lowest C:N ratios were observed in weakly hydrolyzable fractions (2.4:1-4.6:1), whereas the highest ones appeared in nonhydrolyzable ones (18.7:1-29.8:1) – Table 5. The lowest ratios of C:N in weakly hydrolyzable fractions can be to some extent a result of the hydrolysis of bodies of microorganisms, which are relatively resistant to hydrolysis and rich in nitrogen, hence being a significant source of soil nitrogen.

CONCLUSIONS

The results of our studies show that specific environmental conditions of headwater areas have a strong impact on associated organic soils, their properties and vertical distribution of the forms of carbon and nitrogen. The investigated Histosols were rich in SOM (317.3-829.0 g kg^{-1}) and TOC (162.2-459.5 g kg^{-1}). NHC dominated in the pool, with the contribution from 72.3 to 89.2% in TOC. EHC accounted for 6.4-17.2% of TOC (27.3-62.2 g kg^{-1}). The content of TN was 11.08-33.59 g kg^{-1}. Mineral nitrogen constituted 0.26-1.05% of TN and NH_4-N dominated in the pool with concentrations of 0.043-0.337 g kg^{-1} and the contribution in mineral nitrogen from 84.55 to 98.27%. In general, the observed concentrations of NO_3-N were lower and those of NH_4-N higher than observed in organic soils by other authors. Hydrolyzable or nonhydrolyzable forms of nitrogen were major components of TN with the contributions 29.29-61.86% and 37.18-69.84%, respectively, which is consistent with the data of other authors. WHN predominated in the pool of hydrolyzable nitrogen, and its content was 1.4-4.0-fold higher than EHN. Quantitative proportions between hydrolyzable and nonhydrolyzable forms of nitrogen varied vertically. An increase in the content of nonhydrolyzable and a decrease in hydrolyzable forms occyrred with depth. The vertical distribution of nitrogen forms (probably typical for the soils of headwater areas) is an effect of the vertically varied intensity of biochemical processes (maximum one in bog horizons) and intensive leaching of the soils over the mineral bed caused by groundwater. The content of EHC, WHC, NHC, NH_4-N, EHN, WHN and NHN in most cases was significantly positively related to the content of SOM, TOC, TN, but negatively to the TOC:TN ratio.

REFERENCES

Becher M., Kalebasa 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)

Chapman P.J., Reynolds B., Wheater H.S. 1993. *Hydrochemical changes along stream pathways in a small moorland headwater catchment in Mid-Wales.* J. Hydrol., 151: 241-265.

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

Daniels S.M., Evans M.G., Agnew C.T., Allott T.E.H. 2012. *Ammonium release from a blanket peatland into headwater stream systems.* Env. Poll., 163: 261-272.

Davies P.E., McIntosh P.D., Wapstra M., Bunce S.E.H., Cook L.S.J., French B., Munks S.A. 2005. *Changes to headwater stream morphology, habitats and riparian vegetation recorded 15 years after pre-Forest Practices Code forest clearfelling in upland granite terrain, Tasmania, Australia.* For. Ecol. Manage., 217: 331-350.

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.

Devito K.J., Hill A.R., Roulet N. 1996. *Groundwater-surface water inteactions in headwater forested wetlands of the Canadian Shield.* J. Hydrol., 181: 127-147.

Foster H.J., Lees M.J., Wheater H.S., Neal C., Reynolds B. 2001. *A hydrochemical modelling framework for combined assessment of spatial and temporal variability in stream chemistry: application to Plynlimon, Wales.* Hydrol. Earth System Sci., 5(1): 49-58.

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

Grosse-Brauckmann G. 1990. *Ablagerungen der Moore* In: *Moor- und Torfkunde*, Göttlich K. (ed.), E. Schweizerbart'sche Verlagsbuchhandlung, 175-236.

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.

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.

Jekatierynczuk-Rudczyk E. 2007. *The hyporheic zone, its functioning and meaning.* Kosmos, 56(1-2): 181-196. (in Polish)

Jonczak J. 2010. *Sorption and buffer properties of the soils of spring niches in the valley of Jarosławianka River (Sławieńska Plain).* Soil Sci. Ann., LXI(3): 45-51. (in Polish)

Jonczak J. 2011, *Pedological aspects in the functioning of spring niches as transition zones between underground and superficial parts of water cycle in river basin.* Ecol. Questions, 15: 35-43.

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. Cysewska J. 2010. *Taxonomy and selected properties of the soils of spring niches in the valley of the Jarosławianka River (Sławieńska Plain).* Soil Sci. Ann., LXI(2): 45-56. (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. Elementol., 17(3): 409-419.

Karlsson O.M., Richardson J.S., Kiffney P.M. 2005. *Modelling organic matter dynamics in headwater streams of south-western British Columbia, Canada.* Ecol. Model., 183: 463-476.

Mazurek M. 2006. *Groundwater outflows in the southern part of Parsęta drainage basin.* Badania Fizjograficzne nad Polską Zachodnią, Seria A – Geografia Fizyczna, 57: 101-118. (in Polish).

Mazurek M. 2012. *Hydrogeomorphology of the Hades Channel (The Parsęta River drainage basin, NW Poland).* Adam Mickiewicz University Press. Poznań, pp. 304. (in Polish)

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.

Schulten H.R., Schnitzer M. 1998. *The chemistry of soil organic nitrogen: a review.* Biol Fertil. Soils, 26:1-15.

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

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.

Szymczyk S., Pawluczuk J., Stępień A. 2010. *Seasonal variability of mineral nitrogen in groundwater of hydrogenic soils.* J. Elementol., 15(4): 713-723.