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ORIGINAL PAPER

THE CONTENT AND PROFILE DISTRIBUTION OF CARBON AND NITROGEN FRACTIONS SUSCEPTIBLE TO ACID HYDROLYSIS IN HAPLIC CHERNOZEMS AND MOLLIC FLUVISOLS OF WESTERN SLOVAKIA*

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Abstract

The studies on the content and profile distribution of carbon and nitrogen fractions of varied susceptibility to acid hydrolysis were performed in arable Haplic Chernozems and Mollic Fluvisols at four locations near Krakovany, Slovakia. The soils were sampled every 10 cm and analyzed, including the content of total organic carbon (TOC) and nitrogen (TN) and fractions of these elements after sequential extraction in 0.25 mol dm^{-3} KCl, 0.25 mol dm^{-3} H_2SO_4 and 2.5 mol dm^{-3} H_2SO_4. Based on extractions, the content of easy hydrolyzable (EHC), hardly hydrolyzable (HHC) and nonhydrolyzable carbon (NHC) and the content of ammonium nitrogen (NH_4-N), nitrate nitrogen (NO_3-N), dissolved organic nitrogen (DON), easy hydrolyzable nitrogen (EHN), hardly hydrolyzable nitrogen (HHN) and nonhydrolyzable nitrogen (NHN) was calculated. Mollic Fluvisols were more abundant in TOC and TN as compared to Haplic Chernozems. The content of carbon and nitrogen fractions varied among the soils, showing correlations with the total content of these elements. A low contribution of EHC and HHC in TOC and NO_3-N, EHN, HHN in TN and a large share of nonhydrolyzable fractions of these elements were characteristic features of the studied soils. In general, trends in HHC (as % of TOC) and NO_3-N, NH_4-N, EHN (as % of TN), increasing with depth with a simultaneous decrease of NHN were observed. A-horizons of Haplic Chernozems were characterized by a higher contribution of EHN, NH_4-N and NO_3-N in TN, but a lower share of NHN as compared to Mollic Fluvisols.

Keywords: sequential extraction, arable soils, soil organic matter, carbon turnover, nitrogen turnover.

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INTRODUCTION

Carbon and nitrogen cycling is crucial for the functioning of natural and modified terrestrial and aquatic ecosystems. Soils, as the space of interactions between the biosphere and abiotic components, play a particularly large role in this respect in terrestrial ecosystems. Carbon and nitrogen are present in soils in different forms, although the highest amounts are usually incorporated in organic matter. The stock of soil organic carbon and nitrogen, as well as qualitative features of their organic compounds reflect past conditions of soil development under the influence of spatiotemporally varied configurations of soil-forming factors (Poeplau, Don 2013, Łabaz et al. 2014).

A primary source of soil organic carbon and nitrogen is litterfall, which contains about 50% of organic carbon and highly varied amounts of nitrogen, depending on plant species, litter fraction and a complex of environmental conditions determining its bioavailability (Augusto et al. 2002, Jonczak 2011). An annual influx of nitrogen with litterfall to soil in forest ecosystems of the temperate zone is usually several dozen kilos per hectare. An important role in supplying forest soils with this element is also played by throughfall and stemflow (Carnol, Bazgir 2013) as well as the bonding of atmospheric nitrogen by microorganisms (Lorenz, Lal 2010). Regardless of the size of supply, the demand for nitrogen in natural ecosystems is usually much higher, thus nitrogen is one of the key elements determining primary production of the biosphere (Elser et al. 2007), and constitutes a factor limiting the development of plant communities and soil microorganisms (Oren et al. 2001). The spatially varied abundance of soils in nitrogen sets ranges of plant communities of varied trophic requirements (Matuszkiewicz et al. 2013).

The carbon and nitrogen balance in contemporary ecosystems is usually strongly modified by human activity. It is estimated that in commercial forests, depending on their species composition, site conditions, protective treatments, intensity of exploitation and related factors, litterfall production declined by 20-60% in comparison to natural forests, which is finally reflected in reduced stocks of organic carbon and nitrogen (Karjalainen 1996, Crow et al. 2002). The greatest changes in the carbon and nitrogen balance are due to the transformation of forest ecosystems into arable lands (Davidson, Ackerman 1993, Tan, Lal 2005), which is clearly visible as soon as in the first years after deforestation (Feller et al. 1997, Mund 2004, Lorenz, Lal 2010). The carbon and nitrogen balance in arable soils is strongly conditioned by their removal with crops and supply with organic and mineral fertilizers (Šimanský, Kováčik 2014, Szombathová 2010). The quantity and quality of fertilizers and the character of agrotechnical treatments also influence the speciation of these elements (Jonczak 2013, Šimanský 2013). Quantitative proportions between individual fractions can be a useful measure for the assessment of soils' ecological condition and their susceptibility/resistance to the impact of external factors (Šimanský 2013, Šimanský et al. 2015).

Our aim was to compare the content and profile distribution of carbon and nitrogen fractions in spatiotemporally associated arable Haplic Chernozems and Mollic Fluvisols of western Slovakia, based on sequential extraction.

MATERIAL AND METHODS

Stand characteristics

The studies were performed near Krakovany (48°36′39.62″ N 17°45′7.28″ E, altitude about 165 m a.s.l.), western Slovakia. The average annual temperatures for this region are about 8.5-9.0°C and annual sums of precipitation equal 650-800 mm. Two soil pits were dug within the complex of arable Haplic Chernozems associated with Pleistocene loess covers and two other pits were made within the complex of arable Mollic Fluvisols developed from Quaternary fluvial deposits of the Váh river. The following crops were grown in the investigated stands during the study year: soya (*Glycine max* L.) on Haplic Chernozem 1 stand (Ch1), sunflower (*Helianthus annus* L.) on Haplic Chernozem 2 stand (Ch2) and corn (*Zea mays* L.) on both stands of Mollic Fluvisols (MF1 and MF2). The alluvium of the Váh River and lower parts of the slopes are classified into the Pannonian flora (Pannonicum), the phytogeographical district Danubian Plain (Futák 1980). Although the soils studied have been used as arable fields for centuries, the indigenous growth was Oak-hornbeam Pannonian forest on the Haplic Chernozems and willow--poplar forest on the Mollic Fluvisols wetlands (Michalko et al. 1986).

Soil sampling and analysis

The soils were described after the WRB (2014) and sampled every 10 cm. Three undisturbed volumetric samples using 200 cm^3 steel cylinders and one disturbed sample were collected from each layer and analyzed, including:

- particle density (ρ_s) by pycnometry;
- bulk density (ρ_d) by the gravimetric method;
- total porosity was calculated according to the formula $(\rho_s - \rho_d)/\rho_s \cdot 100$;
- soil moisture (θ) – gravimetrically (Hrivňáková et al. 2011);
- pH – potentiometrically in soil-water suspension in the 1:2.5 ratio;
- the content of carbonates with the Scheibler method;
- the content of total organic carbon (TOC) by the Tyurin method (Orlov, Grishina 1981);
- the content of total nitrogen (TN) with the Kjeldahl method;
- sequential extraction of carbon and nitrogen fractions using 0.25 mol dm^{-3}

KCl, 0.25 mol dm^{-3} H_2SO_4 and 2.5 mol dm^{-3} H_2SO_4 as extractants (Kalembasa 1995).

The following fractions of carbon and nitrogen were separated:

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

The content of carbon fractions in extracts was analyzed after evaporation by the Tyurin method, organic nitrogen with the Kjeldahl method, ammonium nitrogen by water steam distillation and nitrate nitrogen colorimetrically with sodium salicylate.

The Spearman's linear correlation coefficients between the TOC and TN content and fractions of these elements were determined using a correlation matrix, in Statistica software.

Soil morphology and basic properties

The studied soils were 80-90 cm thick. The bulk density in Haplic Chernozems ranged from 1.24 to 1.61 g cm^{-3} and that of Mollic Fluvisols was from 1.17 to 1.54 g cm^{-3}, with the maximum in the compacted subsoil in profiles Ch1, Ch2 and MF1 and in the parent material in profile MF2. Total porosity ranged from 35.4 to 53.7% (Table 1) and moisture from 19.9 to 33.0 vol.%. Soil pH varied widely from neutral to alkaline in A-horizons and increased with depth in a result of the increasing content of carbonates and the influence of groundwater in Mollic Fluvisols.

Table 1

Basic properties of the studied soils

Horizon	Depth (cm)	Bulk density (ρ_d) (g cm^{-3})	Total porosity (% vol.)	Moisture (θ) (% vol.)	pH_{H_2O}	$CaCO_3$ (%)
Haplic Chernozem 1 (Ch1)						
Ahp	0-10	1.38	43.7	33.0	7.5	0.3
Ah2	10-20	1.61	35.4	32.7	7.5	0.2
	20-30	1.54	40.5	32.0	7.6	0.1
Ah3	30-40	1.58	38.9	32.0	7.7	0.1
	40-50	1.44	44.8	29.7	7.8	0.4
Ah4	50-60	1.40	46.3	30.3	7.9	0.2
	60-70	1.39	47.3	29.8	7.9	0.4
	70-80	1.37	47.1	29.3	7.9	0.7
ACk	80-90	-	-	-	8.0	7.1
Ck	90-100	-	-	-	8.2	17.2
	100-110	-	-	-	7.8	21.8
Haplic Chernozem 2 (Ch2)						
Ahp	0-10	1.24	52.6	25.7	6.7	0.0
	10-20	1.35	47.9	30.6	6.6	0.0
Ah2	20-30	1.27	51.0	27.8	6.7	0.2
Ah3	30-40	1.48	42.9	31.5	7.4	0.0
	40-50	1.40	46.2	30.9	7.8	0.3
	50-60	1.34	48.7	27.3	7.8	0.3
	60-70	1.35	48.7	28.8	7.9	0.9
ACk	70-80	1.30	50.6	27.5	8.0	7.5
Ck	80-90	-	-	-	8.1	16.5
	90-100	-	-	-	8.1	21.2
	100-110	-	-	-	8.1	20.4
Mollic Fluvisol 1 (MF1)						
Ahkp	0-10	1.42	43.7	31.6	7.8	1.2
	10-20	1.54	40.0	29.9	7.8	2.1
Ahk	20-30	1.53	40.8	28.2	7.9	6.0
ACgck	30-40	1.48	43.4	25.1	8.0	13.4
Ckgc/A	40-50	1.47	44.2	23.8	8.1	20.4
	50-60	1.49	43.8	18.1	8.1	26.8
	60-70	1.49	44.0	17.9	8.1	20.2
	70-80	1.49	44.3	19.9	7.9	23.3
Ckg	80-90	1.50	44.1	24.3	8.3	28.0
	90-100	-	-	-	8.3	27.3
Mollic Fluvisol 2 (MF2)						
Ahp	0-10	1.17	53.7	22.0	7.2	0.0
	10-20	1.39	45.5	24.0	7.3	0.0
	20-30	1.32	48.0	24.6	7.4	0.0
Ah	30-40	1.44	43.6	27.6	7.6	0.0
ACkg	40-50	1.45	43.7	25.3	7.8	3.0
Ckg/A	50-60	1.47	43.7	24.3	7.9	10.9
	60-70	1.46	44.0	23.7	7.9	20.2
	70-80	1.47	44.4	20.5	8.0	23.5
Ckg	80-90	1.53	42.1	23.8	8.2	27.0

RESULTS AND DISCUSSION

Chernozems and related chernozemic soils, like Mollic Fluvisols, are considered as one of the most valuable components of the pedosphere, developed as a result of intensive accumulation of humic substances. Humus-rich, thick A-horizons with granular structure are a common feature of these soils. Owing to high fertility and productivity, chernozemic soils have been intensively tilled for many centuries, which is reflected in their morphology, physical and chemical properties (Zamuner et al. 2008, Deubel et al. 2011) and in quantitative and qualitative features of humus (Gajić 2013, Tobiašová et al. 2013, Głąb, Gondek 2014). Nowadays, these soils are generally degraded in varying degrees, with a reduced content of organic matter, distorted proportions between the various components and modified water balance. However, susceptibility to degradation varies among different groups of chernozemic soils, depending on their position in the landscape and a complex of physical and chemical properties.

The studied Haplic Chernozems and Mollic Fluvisols function in the same landscape and are spatiotemporally related. Both soils are characterized by the presence of thick A-horizons and high abundance in organic matter. The content of TOC in Haplic Chernozems ranged from 4.20 to 13.70 g kg^{-1}, showing generally decreasing trends with depth (Table 2). TOC content in Mollic Fluvisols was 11.80-23.10 g kg^{-1}. The content of TN was up to 1.425 g kg^{-1} in Haplic Chernozems and 2.442 g kg^{-1} in Mollic Fluvisols, and decreased with depth in every profile (Table 3).

The studied soils were characterized by the low susceptibility of carbon and nitrogen organic compounds to acid hydrolysis, which is probably an effect of the predominance of humic acids over fulvic acids and high persistence of organo-mineral components (Monreal et al. 1995, 2010, Szombathová 2010). The NHC fraction constituted 86.7-93.3% TOC in Haplic Chernozems and 90.8-94.6% TOC in Mollic Fluvisols (Figure 1), at the content of 3.64-12.79 g kg^{-1} and 2.56-21.51 g kg^{-1}, respectively (Table 2). The content of NHC (as % of TOC) was higher than reported by Becher and Kalembasa (2011) in Cambisols and Luvisols of the Siedlce Upland and by Jonczak (2014) in Stagnic Luvisols under different use in northern Poland, as well as in organic soils in the valley of the Liwiec River (Kalembasa, Becher 2009) and Kamienna Creek (Jonczak 2014). HHC usually predominated among hydrolyzable carbon fractions, constituting 4.2-6.6% TOC (0.26-0.60 g kg^{-1}) in Haplic Chernozems and 3.4-6.8% TOC (0.13-1.11 g kg^{-1}) in Mollic Fluvisols. The content of EHC ranged from 2.3-6.6% TOC (0.11-0.52 g kg^{-1}) and 1.7-3.5% TOC (0.07-0.71 g kg^{-1}), respectively. In general, the profile and vertical variability in contribution of carbon fractions in TOC was low (Figure 1).

The predominant fraction of nitrogen was NHN, which constituted 65.9-86.7% TN (0.327-1.095 g kg^{-1}) in Haplic Chernozems and 46.5-89.6% TN (0.109-2.187 g kg^{-1}) in Mollic Fluvisols. It is more than reported by other authors (Kalembasa, Becher 2009, Becher, Kalembasa 2011, Jonczak 2014,

Table 2

The content of carbon fractions in the studied soils

Horizon	Depth (cm)	TOC	EHC	HHC	NHC
		(g kg^{-1})			
Haplic Chernozem 1 (Ch1)					
Ahp	0-10	13.70	0.52	0.59	12.59
Ah2	10-20	9.80	0.52	0.50	8.78
	20-30	10.30	0.41	0.44	9.45
Ah3	30-40	8.60	0.36	0.39	7.86
	40-50	7.40	0.29	0.34	6.77
Ah4	50-60	5.70	0.33	0.26	5.11
	60-70	5.30	0.33	0.29	4.68
	70-80	4.20	0.28	0.28	3.64
ACk	80-90	4.80	0.25	0.31	4.25
Haplic Chernozem 2 (Ch2)					
Ahp	0-10	12.90	0.44	0.54	11.92
	10-20	13.70	0.33	0.58	12.79
Ah2	20-30	12.60	0.42	0.60	11.58
Ah3	30-40	10.00	0.23	0.56	9.20
	40-50	8.20	0.25	0.35	7.60
	50-60	6.80	0.22	0.32	6.26
	60-70	5.00	0.11	0.30	4.59
ACk	70-80	6.40	0.24	0.35	5.81
Mollic Fluvisol 1 (MF1)					
Ahkp	0-10	22.40	0.71	1.11	20.59
	10-20	18.40	0.56	0.94	16.89
Ahk	20-30	11.80	0.41	0.59	10.81
ACgck	30-40	8.40	0.16	0.29	7.95
Ckgc/A	40-50	5.50	0.15	0.34	5.01
	50-60	4.40	0.10	0.25	4.05
	60-70	2.80	0.07	0.18	2.56
	70-80	3.10	0.08	0.13	2.89
Mollic Fluvisol 2 (MF2)					
Ahp	0-10	22.30	0.71	1.00	20.58
	10-20	23.10	0.65	0.94	21.51
	20-30	22.80	0.66	0.91	21.22
Ah	30-40	14.40	0.46	0.58	13.36
ACkg	40-50	9.30	0.32	0.48	8.50
Ckg/A	50-60	6.60	0.19	0.41	5.99
	60-70	5.90	0.12	0.36	5.43
	70-80	6.20	0.10	0.42	5.68

TOC – total organic carbon, EHC – easy hydrolyzable carbon, HHC – hardly hydrolyzable carbon, NHC – nonhydrolyzable carbon

Jonczak et al. 2014). Susceptibility to hydrolysis of organic nitrogen strongly varied in profiles and tended to be higher in the topsoil as compared to the subsoil and transitional horizons (Figure 2). HHN amounted to 0.003-0.089 g

Table 3

The content of nitrogen fractions in the studied soils

Horizon	Depth (cm)	TN	NH_4-N	NO_3-N	DON	EHN	HHN	NHN
		(g kg^{-1})						
Haplic Chernozem 1 (Ch1)								
Ahp	0-10	1.425	0.064	0.003	0.012	0.162	0.089	1.095
Ah2	10-20	1.209	0.045	0.002	0.012	0.122	0.087	0.940
	20-30	1.104	0.048	0.002	0.011	0.083	0.031	0.929
Ah3	30-40	0.941	0.051	0.002	0.005	0.099	0.011	0.773
	40-50	0.961	0.042	0.002	0.014	0.084	0.013	0.807
Ah4	50-60	0.940	0.056	0.002	0.004	0.069	0.003	0.805
	60-70	0.847	0.038	0.002	0.013	0.071	0.003	0.719
	70-80	0.516	0.043	0.002	0.016	0.071	0.003	0.381
ACk	80-90	0.484	0.042	0.002	0.007	0.078	0.003	0.350
Haplic Chernozem 2 (Ch2)								
Ahp	0-10	1.138	0.064	0.002	0.038	0.079	0.060	0.894
	10-20	1.139	0.068	0.003	0.005	0.076	0.040	0.946
Ah2	20-30	1.138	0.040	0.003	0.006	0.079	0.023	0.987
Ah3	30-40	0.797	0.039	0.001	0.034	0.077	0.026	0.619
	40-50	0.604	0.043	0.001	0.016	0.049	0.026	0.469
	50-60	0.681	0.028	0.001	0.028	0.046	0.037	0.540
	60-70	0.478	0.041	0.001	0.006	0.050	0.039	0.340
ACk	70-80	0.497	0.035	0.001	0.026	0.056	0.051	0.327
Mollic Fluvisol 1 (MF1)								
Ahkp	0-10	2.344	0.040	0.003	0.043	0.097	0.117	2.044
	10-20	2.165	0.043	0.003	0.039	0.077	0.101	1.902
Ahk	20-30	1.267	0.040	0.002	0.012	0.068	0.059	1.086
ACgck	30-40	0.889	0.039	0.002	0.005	0.080	0.044	0.719
Ckgc/A	40-50	0.586	0.040	0.002	0.007	0.070	0.028	0.439
	50-60	0.416	0.050	0.002	0.002	0.072	0.018	0.273
	60-70	0.233	0.055	0.002	0.001	0.064	0.003	0.109
	70-80	0.244	0.050	0.002	0.001	0.072	0.003	0.115
Mollic Fluvisol 2 (MF2)								
Ahp	0-10	2.442	0.056	0.003	0.011	0.107	0.077	2.187
	10-20	2.158	0.064	0.006	0.023	0.112	0.052	1.901
	20-30	2.009	0.060	0.006	0.003	0.122	0.049	1.769
Ah	30-40	1.170	0.047	0.003	0.001	0.098	0.035	0.986
ACkg	40-50	0.747	0.053	0.002	0.000	0.073	0.022	0.595
Ckg/A	50-60	0.652	0.053	0.003	0.001	0.068	0.020	0.507
	60-70	0.509	0.042	0.004	0.022	0.050	0.016	0.375
	70-80	0.497	0.042	0.005	0.019	0.037	0.014	0.379

TN – total nitrogen, NH_4-N – ammonium nitrogen, NO_3-N – nitrate nitrogen, DON – dissolved organic nitrogen, EHN – easy hydrolyzable nitrogen, HHN – hardly hydrolyzable nitrogen, NHN – nonhydrolyzable nitrogen

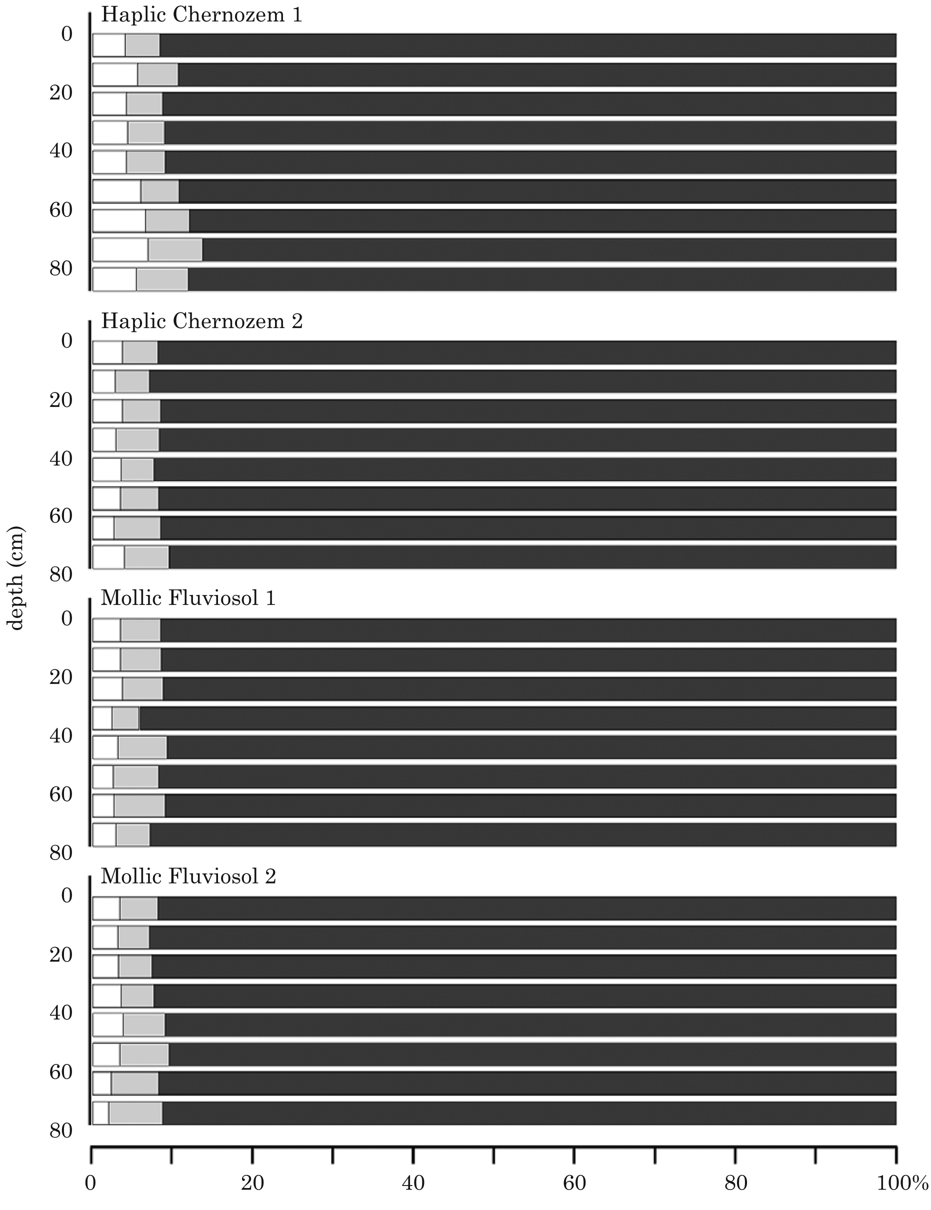

Fig. 1. The contribution of easily hydrolyzable (EHC), hardly hydrolyzable (HHC) and nonhydrolyzable (NHC) carbon fractions into total organic carbon

kg^{-1} (0.4-10.3% TN) in Haplic Chernozems and 0.003-0.117 g kg^{-1} (1.4-5.0% TN) in Mollic Fluvisols, EHN in 0.046-0.162 g kg^{-1} (6.7-16.1% TN) and 0.037-0.122 g kg^{-1} (3.6-29.7% TN) and DON in 0.004-0.038 g kg^{-1} (0.4-5.2%

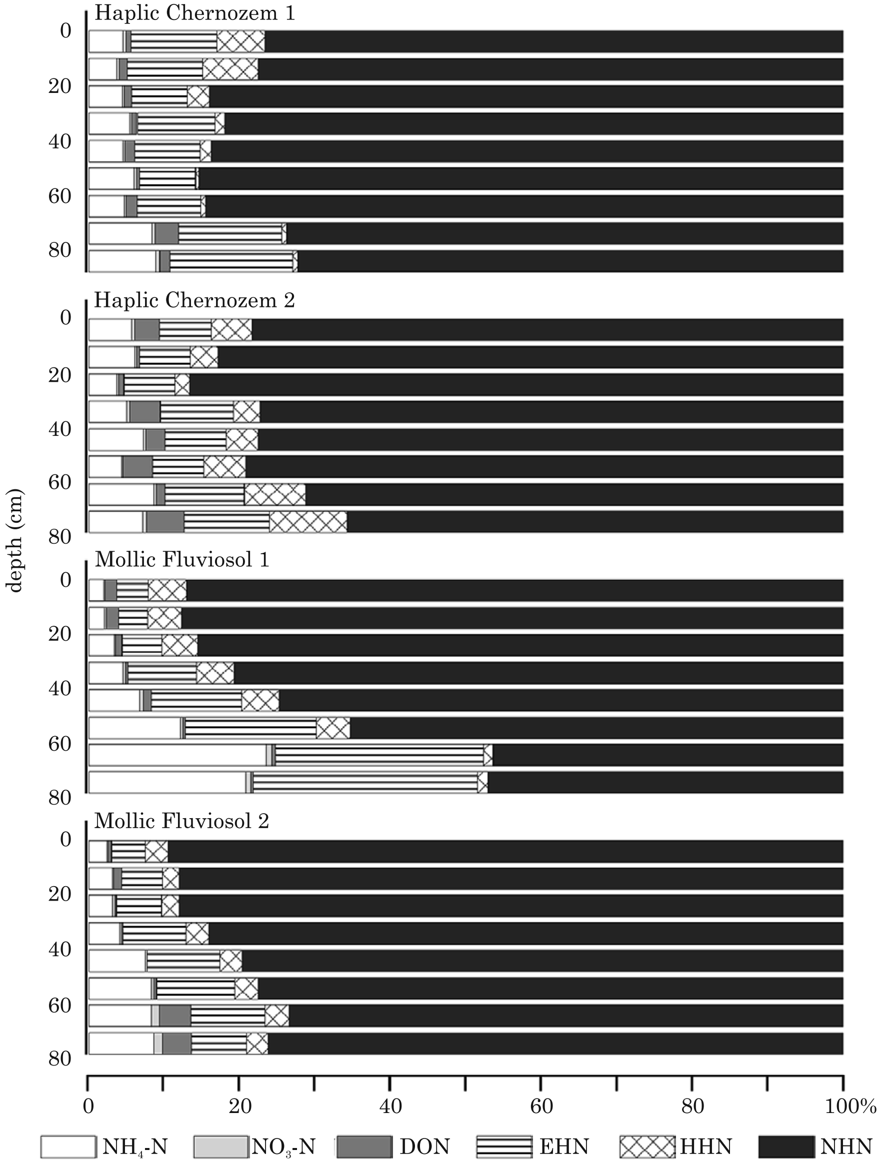

Fig. 2. The contribution of ammonium (NH_4-N), nitrate (NO_3-N), dissolved organic (DON), easy hydrolyzable (EHN), hardly hydrolyzable (HHN) and nonhydrolyzable (NHN) nitrogen fractions into total nitrogen

TN) and 0.000-0.043 g kg^{-1} (0.0-4.4% TN), respectively. The content of EHN (as % of TN) was in general lower than observed by the authors mentioned above. DON, as a component of labile organic matter, is a product of micro -biochemical transformations of plant and animal residues (CURRIE et al. 1996). In forest ecosystems, it is produced mainly in ectohumus (JONCZAK, Parzych 2012), where it is usually present in higher amounts than mineral nitrogen (Yu et al. 1994). DON is easily mineralizable and vulnerable to leaching into ground and then to surface waters, thus influencing their quality (Wissmar 1991).

The content of mineral nitrogen, especially in arable soils, is dynamic over time, showing close dependence with the crop type, phase of plants growth, fertilization and a number of factors influencing the size of inflow/outflow and transformations of nitrogen compounds (Li et al. 2013). Due to the high demand for nitrogen, the content of its mineral forms in soils is usually low. The major fraction of mineral nitrogen in the studied soils was NH_4-N, whose share in TN was 3.5-8.8% in Haplic Chernozems and 1.7-23.4% in Mollic Fluvisols (Table 3). NO_3-N occurred in trace amounts, not reaching 0.006 g kg^{-1} and its contribution to TN was usually below 1%.

The high abundance of nitrogen in the investigated soils is reflected in the low C:N ratios. TOC:TN in Haplic Chernozems ranged from 6.1:1 to 13.6:1 and in Mollic Fluvisols from 8.5:1 to 12.1:1 (Table 4). In carbon and nitrogen fractions of variable susceptibility to acidic hydrolysis, the C:N ratios were strongly varied, reaching the lowest values in easy hydrolyzable fraction (2.3:1-5.6:1 in Haplic Chernozems and 1.0:1-7.3:1 in Mollic Fluvisols). In general higher, but much more variable, were the HHC:HHN and NHC:NHN ratios, which in Haplic Chernozems ranged from 5.8:1 to 89.6:1 and from 6.3:1 to 17.8:1 respectively, while in Mollic Fluvisols from 6.6:1 to 51.8:1 and from 8.9:1 to 25.1:1 (Table 4).

CONCLUSIONS

Situated in the rural landscape of western Slovakia, the spatiotemporally related Haplic Chernozems and Mollic Fluvisols analyzed differed in the content of TOC and TN as well as in the content and profile distribution of fractions of these elements of different susceptibility to acid hydrolysis. More abundant were Mollic Fluvisols. In both soil groups, NHC predominated among carbon fractions and NHN was prevalent among fractions of nitrogen. The soils were characterized by a low contribution of EHC and HHC into TOC and NO_3-N, EHN and HHN into TN. The content of the individual fractions in most cases was significantly positively correlated with TOC and TN. The low susceptibility of carbon and nitrogen organic compounds to acid hydrolysis should be considered as an effect of the high stability of humic substances, which is typical for the studied soils. With increasing depth, we increasing tendencies in the contribution of HHC into TOC and NO_3-N, NH_4-N and EHN into TN at a decreasing trend for NHN. The vertical variability in the share of NHC in TOC was low and the remaining fractions showed irregular fluctuations. The A-horizons of Haplic Chernozems contained more EHN, NH_4-N and NO_3-N and less NHN (as % of TN) in comparison with Mollic Fluvisols.

Table 4

The ratios of TOC:TN and C:N in fractions of different susceptibility to acid hydrolysis

Horizon	Depth (cm)	TOC:TN	EHC:EHN	HHC:HHN	NHC:NHN
Haplic Chernozem 1 (Ch1)					
Ahp	0-10	9.6	3.2	6.6	11.5
Ah2	10-20	8.1	4.3	5.8	9.3
	20-30	9.3	5.0	14.3	10.2
Ah3	30-40	9.1	3.6	36.1	10.2
	40-50	7.7	3.5	25.9	8.4
Ah4	50-60	6.1	4.7	76.2	6.3
	60-70	6.3	4.7	85.1	6.5
	70-80	8.1	3.9	80.6	9.6
ACk	80-90	9.9	3.1	89.6	12.1
Haplic Chernozem 2 (Ch2)					
Ahp	0-10	11.3	5.6	8.9	13.3
	10-20	12.0	4.3	14.6	13.5
Ah2	20-30	11.1	5.3	26.2	11.7
Ah3	30-40	12.5	3.0	21.9	14.9
	40-50	13.6	5.1	13.7	16.2
	50-60	10.0	4.8	8.6	11.6
	60-70	10.5	2.3	7.6	13.5
ACk	70-80	12.9	4.3	6.9	17.8
Mollic Fluvisol 1 (MF1)					
Ahkp	0-10	9.6	7.3	9.4	10.1
	10-20	8.5	7.3	9.3	8.9
Ahk	20-30	9.3	6.0	10.0	9.9
ACgck	30-40	9.4	2.1	6.6	11.1
Ckgc/A	40-50	9.4	2.1	12.0	11.4
	50-60	10.6	1.3	13.9	14.9
	60-70	12.0	1.0	51.8	23.6
	70-80	12.7	1.1	37.7	25.1
Mollic Fluvisol 2 (MF2)					
Ahp	0-10	9.1	6.6	13.1	9.4
	10-20	10.7	5.8	17.9	11.3
	20-30	11.4	5.5	18.6	12.0
Ah	30-40	12.3	4.7	16.7	13.5
ACkg	40-50	12.5	4.4	21.5	14.3
Ckg/A	50-60	10.1	2.8	21.1	11.8
	60-70	11.6	2.3	22.4	14.5
	70-80	12.5	2.8	29.4	15.0

Table 5

Spearman's linear correlation coefficients between the content of TOC and TN and fractions of these elements

Specification	NHC	HHC	EHC	TN	NHN	HHN	EHN	DON	NH_4-N	NO_3-N
Haplic Chernozems										
TOC	**1.00**	**0.95**	**0.67**	**0.82**	**0.79**	**0.59**	**0.53**	0.12	**0.63**	**0.72**
NHC		**0.94**	**0.65**	**0.81**	**0.78**	**0.58**	**0.52**	0.12	**0.63**	**0.71**
HHC			**0.61**	**0.73**	**0.69**	**0.59**	**0.55**	0.17	**0.49**	**0.72**
EHC				**0.89**	**0.85**	**0.52**	**0.79**	-0.08	**0.56**	**0.75**
TN					**0.99**	**0.51**	**0.75**	-0.12	**0.65**	**0.77**
NHN						0.39	**0.68**	-0.17	**0.62**	**0.76**
HHN							**0.55**	0.26	0.32	0.37
EHN								-0.20	**0.52**	**0.65**
DON									-0.19	-0.32
NH_4-N										**0.58**
Mollic Fluvisols										
TOC	**1.00**	**0.97**	**0.99**	**0.98**	**0.98**	**0.81**	**0.82**	**0.51**	0.31	**0.50**
NHC		**0.97**	**0.99**	**0.98**	**0.98**	**0.81**	**0.83**	**0.50**	0.32	**0.51**
HHC			**0.97**	**0.98**	**0.98**	**0.87**	**0.69**	**0.63**	0.21	0.47
EHC				**0.97**	**0.97**	**0.82**	**0.82**	0.47	0.30	0.41
TN					**1.00**	**0.89**	**0.76**	**0.59**	0.22	0.39
NHN						**0.89**	**0.76**	**0.58**	0.22	0.40
HHN							**0.52**	**0.75**	-0.18	0.09
EHN								0.04	**0.54**	0.30
DON									-0.35	0.23
NH_4-N										0.41

In bold correlations statistically significant at $p < 0.05$, $n = 17$ in Haplic Chernozems and $n = 16$ in Mollic Fluvisols.

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