Accumulation of C_t and N_t in humus and mineral soil layers: the effect of change of tree species composition in nudal beech forests

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Abstract

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The effect of change of tree species composition on the content of carbon and nitrogen in surface humus and mineral soil layers was studied in the Kremnické vrchy Mts, in the phytocoenoses of forest type group *Fagetum pauper*. Research was conducted in six forest stands, which represented the natural mature beech stand and five changed stands – birch, spruce, larch, pine and beech pole stage. The research results showed that change of tree species composition had a partial influence on the content of C_t and N_t in soil layers of analyzed phytocoenoses. It was reflected the most in surface humus and topsoil 0–5 cm layers. The highest C_t content was found in surface humus of coniferous stands; in the case of N_t it was in humus horizons of deciduous trees. In the mineral soil layers significantly higher contents of C_t and N_t were found in coniferous stands, in comparison with deciduous stands. Forest stands with changed tree species composition showed a higher content of studied elements in humus horizons as well as in mineral soil layers. In deciduous stands higher C/N ratio was found in mineral layers in comparison with coniferous stands. Stands with changed tree species composition had higher C/N ratio in the subhorizons Ool, and towards to the depth profiles it decreased. Statistically significant differences were found out only in the 0–5 cm soil layers.

Keywords

cambisols, carbon, nitrogen, nudal beech forest, tree species edificator

Introduction

Trees are the basic attribute of the forest communities. They produce the main part of the phytomass. It is organic matter – dropped leaves and needles, which has very important role as natural fertilizer and it is significant for forest existence and for forest soil (Šály, 1988). When dropped leaves and needles die back, the decomposition process begins. Decomposition is very important in the biochemical nutrient cycle, where nutrients are mineralized and provided to vegetation again. Speed of decomposition and nutrient release from organic material are influenced by climate conditions and quality of litter fall (Vesterdal et al., 1995). This fact is reflected in the properties of surface humus and upper soil layers (Binkley and Valentine, 1991; Binkley, 1995; Neirycnk et al., 2000; Augusto et al., 2002, Thorn et al., 2004).

Carbon and nitrogen contents belong to the most important macroelements that determine fertility of the soils (Johnson and Curtis, 2001). Content of these two elements has attracted the attention of many authors (Johnson and Curtis, 2001; Berger et al., 2002; Jandl et al., 2007; Menšík et al., 2009; Guenet et al., 2013). In general the amount of carbon contained in soil is twice higher than in the atmosphere, and three times higher than in the vegetation (Schimel, 1995; Guenet et al., 2013). That is the reason why the soil environment is considered as the most important reservoir of carbon, because it is very dynamic and it belongs to the most significant environment in the existing carbon cycles (Bielek, 2007).

Nitrogen as the most important macroelement is in N_2 form in the highest amount contained in atmosphere (78%). N_2 form is unavailable for plants. Exceptions are plants, which have symbiotic relationship with nitrogenfixing microorganisms. Primary organisms can receive nitrogen in the nitration form (NO_3), or in ammonium salts (NH_4NO_3). Content of these compounds is the result of the biological process in soil (Pelíšek, 1964). In forest ecosystems nitrogen is considered to be one of the limited factors and it has impact on the primary production. Lack of N in the soil is reflected with stunted growth of plants, light green leaves and premature leaves shedding. On the other hand, excess of nitrogen prolonged period of shoot growth until the frosts that deplete immature shoots (Kuklová et al., 2011).

Nitrogen and carbon content is determined by the difference between input and output speed from soil. Therefore tree species are considered to be one of the significant factors that manage the rate of biochemical processes in the soils (Vesterdal et al., 2008; Augusto et al., 2002). With this background, the present study was undertaken with the objective to compare the effect of tree species composition on carbon content (C), nitrogen content (N) and C/N ratio in the humus and mineral soil layers in natural and changed phytocoenoses of forest type group *Fagetum pauper*.

Material and methods

Study site

Geobiocenological plots were situated in the middle Slovakia in the southeast of orographic unit Kremnické vrchy Mts (48°41'N; 18°44'E). Research plots belong to cadastre municipalities of Tŕnie and Sliač, in 580–690 m above sea level, on the SW and SE exposure with 10–20° slopes (Table 1). Research plots are represented by original 80–100 years old beech forest (*Fagus sylvatica* L.) (G1) and changed phytocoenosis segments: 30-year-old birch forest (*Betula pendula* var. *carelica* Hämet-Ahti) (G2), spruce forest (*Picea abies* (L.) H. Karst) (G3), larch forest (*Larix decidua* Mill.) (G4), beech forest (*Fagus sylvatica* L.) (G5) and pine forest (*Pinus sylvestris* L.) (G6). All stands belong to forest type group (FTG) *Fagetum pauper.* The studied forest ecosystems are formed under influence of permanent ecological conditions and a result of interspecific competition. For the purpose of the study geobiocoenological typology was used (Zlatník, 1976). Based on present soil properties, bedrock, climate data and floristic composition, every plot was assigned to a correspondent altitudinal vegetation zone and trophic range (geobiocoenoses G1, G4 – 3rd oak-beech zone, G2, G3, G5, G6 – 4th beech zone). From the edaphic-ecological point of view studied forest stands belong to the mesotrophic range of geobiocoenoses.

The annual mean precipitation reported from the nearest weather station is 690 mm and annual mean temperature is 7.3 °C, available at: http://www.emsbrno.cz/p.axd/sk/Boky.Sever.pri.Budci.TUZVO.html [cited 2013-10-02]. Soils of study stands are dystric cambisols (G1, G2, G5, G6) and skeli-dystric cambisols (G3, G4), created from neo-volcanic andesite tuffs. The average value of the active soil reaction (pH_{H_2O}) ranges from 5.77 to 5.36, exchange reaction (pH_{KCl}) from 4.09 to 4.57 (Šimková et al., 2013). In the soil profiles of study stands dominated silt fraction, the size of 0.01–0.05 mm. Proportion of these fractions represented 30–40%. According to triangle texture diagram (Bedrna et al., 2000), medium-deep soils occurred there, mostly clay loam (G1–G5), partly loam (G1). In the case of site G6 (pine stand), it is covered by sandy loam soil (Table 2) (Šimková, 2013).

Table 1. Basic characteristics of study forest ecosystems

Site / stand age	Tree species edificator	Location	Altitude [m]	Slope [°]	Exposure	Canopy closure [%]
G1 (80–100 y.)	*Fagus sylvatica*	48°37´38" 19°01´40“	645	20	SW	90
G2 (30 y.)	*Betula pendula* var. *carelica*	48°37´04" 19°01´26“	635	10	SE	90
G3 (30 y.)	*Picea abies*	48°37´18" 19°01´35“	625	10	E	90–100
G4 (30 y.)	*Larix decidua*	48°37´07" 19°01´20“	630	15	SW	80
G5 (30 y.)	*Fagus sylvatica*	48°38´91" 19°02´44“	690	10	S	100
G6 (30 y.)	*Pinus sylvestris*	48°36´49" 19°02´15“	580	20	SW	80–90

Table 2. Ecological characteristics of study soils

Site / Edificator	Soil subtype*	Soil reaction $pH_{(H_2O)}$	Soil reaction $pH_{(KCl)}$	Layer [cm]	Skeleton % vol	Fine earth fraction [mm]			Soil class
						Clay [%]	Silt [%]	Sand [%]	
G1 / 80–100 y. *Fagus sylvatica*	Dystric Cambisols	5.38	4.09	0–5	0	27.03	30.33	42.54	Loam
				10–20	10–20	31.71	27.70	40.49	
				20–30	10–20	30.62	33.48	35.81	Clay loam
G2 / 30 y. *Betula pendula* var. *carelica*	Dystric Cambisols	5.77	4.57	0–5	0	30.7	42.63	26.61	Clay loam
				10–20	5–10	34.34	36.02	29.57	
				20–30	5–10	36.27	35.15	28.5	
G3 / 30 y. *Picea abies*	Dystric Cambisols	5.37	4.09	0–5	+	32.66	34.77	32.47	Clay loam
				10–20	10	34.49	30.45	35.01	
				20–30	30–40	40.55	37.39	22.05	
G4 / 30 y. *Larix decidua*	Skeli-Dystric Cambisols	5.36	4.31	0–5	0	31.64	37.97	30.37	Clay loam
				10–20	20–30	30.23	30.68	38.87	
				20–30	60	29.15	28.04	42.68	
G5 / 30 y. *Fagus sylvatica*	Dystric Cambisols	5.42	4.12	0–5	10	32.5	38.60	28.85	Clay loam
				10–20	20	37.5	38.67	23.79	
				20–30	20	37.77	35.71	26.46	
G6 / 30 y. *Pinus sylvestris*	Dystric Cambisols	5.37	4.43	0–5	10	22.23	26.31	51.43	Sandy loam
				10–20	30–40	24.36	20.47	55.14	
				20–30	30–40	24.36	24.50	51.14	

*(WRB, 1994).

Methods

The research was conducted from June to July 2009. Samples of surface humus (subhorizon Ool – leaf litter: from leafs, cupules, sticks, bark and the residue of forest plants without intensive decomposition; subhorizon Oof – fermentation horizon, with partial plant residue decomposition but with distinguishable original structure) were collected from square miniplots (0.1 m^2) in three random repetitions on each plot. The dry weight was obtained by drying the samples during 48-hours at a temperature of 80 °C to a constant weight with a precision 0.002 g. The material was homogenized in a planetary micro mill (<0.001 mm).

Mineral soil samples were taken from 0–5 cm, 10–20 cm and 20–30 cm layers. The soil samples were air-dried and passed through a sieve with a mesh size of 2 × 2 mm. The adjusted samples of surface humus and mineral soil were prepared for analysis and the results converted into the percentage of dry matter in the samples. The Flash 112 analyzer was used to determinate the total carbon and nitrogen contents in samples according to standards STN ISO 10 694 (for carbon) and STN ISO 13 878 (for nitrogen). Ratio C / N was calculated as a nitrogen and carbon total contents.

To characterize the basic information about the studied variables (mean, standard deviation) the descriptive statistics in program SAS was used (StatSoft, Inc., 2010). The effect of change of tree species edificator on the contents of total carbon, nitrogen and ratio C / N in surface humus and mineral soil layers was analyzed by one-way anova. The Fisher LSD test was used to detect significant differences between study plots, groups of tree species (coniferous and deciduous) and also between natural and changed tree-species composition.

Results

Carbon content

A result of carbon content in surface humus and mineral soil samples proved that C_t content decreased with depth of the soil profiles. Content of C_t in the subhorizont Ool ranged from 47.08% in 30-year-old birch stand to 54.89% in 30-year-old larch stand. This difference was 14.22%. In adult beech stand content of C_t in subhorizon Ool represented 52.12% (Fig. 1).

Carbon content was lower in subhorizons Oof than in subhorizons Ool. This was probably associated with gradual release during decomposition process. The highest carbon content was detected in 30-year-old larch forest (51.6%) and the lowest was in 30-year-old birch stand (46.96%). This difference represented 9.15%. In adult beech forest content of C_t in subhorizon Oof represented 49.46%. Statistical evaluation of results showed that values of carbon contents in Ool differed from mature beech forest only with 30-year-old birch stand ($F_{(1,4)}$ = 10.84; p = 0.031). In subhorizons Oof there were not found out any significant differences.

On average, surface humus of deciduous stands contained lower carbon content than humus of coniferous stands. The difference between compared tree

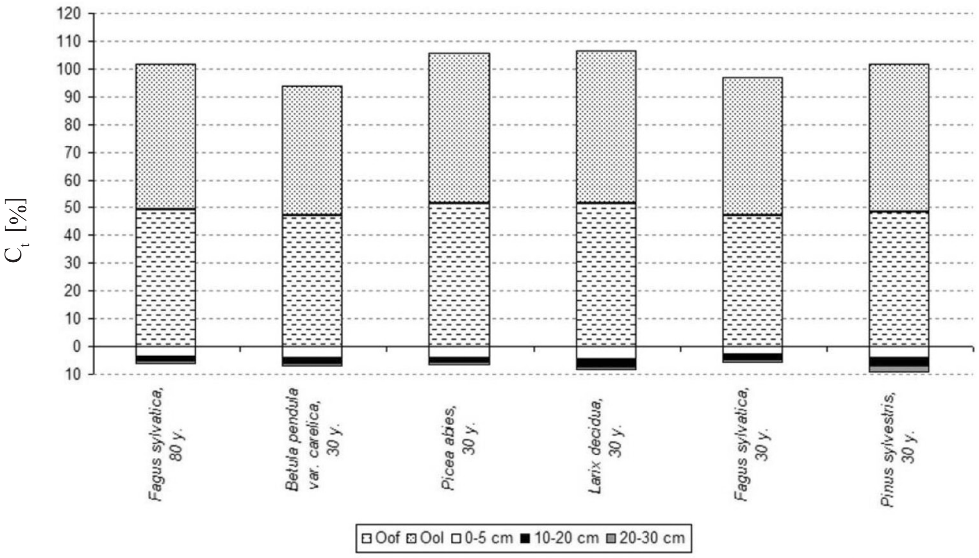

Fig. 1. Content of carbon in soils of studied forest stands.

species groups was 6.8% and it was statistically significant ($F_{(1,34)}$ = 7.726; p = 0.011). In subhorizon Ool the carbon content was higher in stands with altered species composition than in the original species composition. On the contrary, this result has not been demonstrated in the subhorizont Oof. Differences between compared subhorizons were statistically significant ($F_{(1,16)}$ = 3.251; p = 0.04 (Ool); $F_{(1,16)}$ = 3.585; p = 0.043 (Oof); Table 3).

The highest carbon accumulation was detected in 30-year-old larch forest stand in the 0–5 cm depth (4.8%). The lowest one was in the beech forest (3.23%). Similar results were found in the 10–20 cm and 20–30 cm soil layers, too. The highest carbon content was accumulated in the pine forest (2.61%, respectively 2.42%), and the lowest in 30-year-old beech forest (1.34 respectively 1.23%). The most significant differences were found in the case of 80–100-year-old beech forest opposite larch stand (0–5 cm, 10–20 cm) and pine stand (10–20 cm layers) (Table 3).

Mineral soil layers in deciduous stands contained less carbon, than mineral soil in coniferous stands but differences were significant in the 0–5 cm ($F_{(1,16)}$ = 14.279; p = 0.017) and 10–20 cm ($F_{(1,16)}$ = 10.475; p=0.046) soil layers, only. Higher carbon content in soil layers was demonstrated in forest stands with altered tree species composition than in the natural beech forests. Differences were statistically significant in the 0–5 cm soil layer, only ($F_{(1,16)}$ = 63.183; p = 0.021, Table 3).

Nitrogen content

The nitrogen content accumulated in subhorizon Ool ranged from 1.02% in the 30-year-old pine stand to 1.92% in 30-year-old birch stand (Fig. 2). The difference between phytocoeonoses represented 46.3%. Amount of N_t contained in subhorizon Oof ranged from 1.13% to 1.71%. The minimum values were found in pine stand, maximum in birch stand. The difference represented 33.9% and was statistically significant ($F_{(1,4)}$ = 22.42; p = 0.009 (Ool); $F_{(1,4)}$ = 9.73; p = 0.035 (Oof)).

Based on the results, we can conclude, that on average, higher content of N_t in Oo horizons was in the case of deciduous stands in comparison with coniferous stands. This difference was statistically significant ($F_{(1,34)}$ = 13.385; p = 0.048).

Depending on originality of woody plant on studied plots, higher content of N_t in Oo horizons was recorded in the stands with altered species composition in comparison with beech stands, but without significant difference (Table 3).

The highest value of N_t in organo-mineral soil layer 0–5 cm was recorded in the 30-year-old birch stand (0.35%), the lowest in adult beech phytocoenosis (0.18%). In the 10–20 cm layer there was the largest content of nitrogen observed again in the birch stand (0.21%), the lowest in the adult beech stand (0.10%). The differences between the compared phytocoenoses were statistically significant ($F_{(1,4)}$ = 70.61; p = 0.0018 (0–5 cm); $F_{(1,4)}$ = 25.9; p = 0.007 (10–20 cm)). In the 20–30 cm mineral soil layers content of N_t ranged from 0.08% (adult beech phytocoenosis) to 0.18% (30-year-old pine stand). In the layer 0–5 cm statistically significant differences were observed in the case of 80–100-year-old beech stand opposite birch, pine, spruce and pine edificators. In the layer 10–20 cm it was observed between mature beech stand opposite

Table 3. Mean (±SD) C_t, N_t content (%) and C/N ratio in the surface humus and mineral soil layers

Subhorizonts	Ool – horizon			Oof – horizon			0–5 cm			10–20 cm			20–30 cm		
Plot/Tree species edificator	C [%]	N [%]	C/N	C [%]	N [%]	C/N	C [%]	N [%]	C/N	C [%]	N [%]	C/N	C [%]	N [%]	C/N
G1/Beech	52.12^{bc} (0.93)	1.49^{ac} (0.21)	35.51^{ab} (4.85)	49.46^{ab} (2.58)	1.43^{ab} (0.15)	35.92^{ab} (4.87)	3.73^{bc} (0.34)	0.18^{c} (0.02)	20.04^{b} (3.61)	1.37^{a} (0.26)	0.10^{a} (0.03)	16.22^{a} (6.22)	1.3^{a} (0.27)	0.08^{a} (0.02)	15.7^{a} (4.6)
G2/Birch	47.08^{a} (0.75)	1.92^{c} (0.23)	24.73^{a} (4.07)	46.96^{a} (12.9)	1.71^{a} (0.31)	27.3^{b} (3.62)	4.42^{ab} (0.25)	0.35^{a} (0.02)	12.25^{a} (1.54)	1.75^{a} (0.06)	0.21^{b} (0.02)	9.35^{ab} (1.35)	1.23^{a} (0.05)	0.12^{ab} (0.01)	10.47^{ab} (0.82)
G3/Spruce	53.75^{bc} (1.67)	1.31^{a} (0.06)	40.98^{ab} (1.83)	51.64^{ab} (2.02)	1.17^{b} (0.13)	44.71^{c} (1.69)	4.41^{ab} (0.06)	0.33^{ab} (0.02)	13.21a (0.88)	1.4^{a} (0.11)	0.14^{ab} (0.02)	10.39^{a}b (1.77)	1.34^{a} (0.06)	0.11^{a} (0.03)	8.69^{b} (2.09)
G4/Larch	54.89^{b} (0.81)	1.55^{bc} (0.10)	35.47^{ab} (2.84)	51.69^{b} (0.30)	1.51^{ab} (0.11)	34.32^{ab} (2.03)	4.8a (0.35)	0.3^{ab} (0.01)	14.57^{ab} (0.7)	2.37^{b} (0.22)	0.18^{ab} (0.01)	11.75^{ab} (0.45)	1.35^{a} (0.18)	0.13^{ab} (0.02)	9.18^{ab} (0.73)
G5/Beech	49.45^{c} (2.12)	1.37^{ab} (0.11)	36.44^{ab} (4.44)	47.33^{ab} (1.66)	1.57^{ab} (0.13)	30.32^{b} (3.27)	3.23^{c} (0.25)	0.26^{bc} (0.02)	13.3^{a} (2.03)	1.34^{a} (0.11)	0.17^{ab} (0.03)	8.14^{b} (0.75)	1.33^{a} (0.06)	0.14^{ab} (0.02)	9.15^{ab} (1.74)
G6/Pine	53.42^{bc} (3.1)	1.02^{a} (0.23)	54.44^{b} (15.4)	48.36^{ab} (2.69)	1.13^{b} (0.02)	42.69^{ac} (2.77)	4.43^{ab} (0.32)	0.31^{ab} (0.04)	13.67^{a} (0.99)	2.61^{b} (0.16)	0.19^{ab} (0.05)	12.71^{ab} (2.41)	2.42^{a} (0.17)	0.18b (0.02)	12.73^{ab} (1.03)
Broadleaf	49.55* (5.28)	1.59* (0.30)	32.22* (4.35)	47.91* (6.82)	1.57* (0.22)	31.93** (4.71)	3.79* (0.44)	0.26 (0.07)	15.19 (4.26)	1.6* (020)	0.15 (0.04)	11.24 (4.43)	1.28 (0.14)	0.11 (0.03)	10.80 (3.93)
Conifer	54.02 (1.92)	1.29 0.26)	43.62 (11.55)	50.57 (6.52)	1.26 (0.27)	46.48 (7.16)	4.49 (0.27)	0.32 (0.03)	14.05 (1.47)	2.13 (0.55)	0.18 (0.04)	11.60 (1.81)	1.48 (0.65)	0.14 (0.04)	10.21 (2.62)
Natural composition	50.78* (2.07)	1.42 (0.16)	35.97 (4.19)	49.05* (2.70)	1.49 (0.14)	33.12 (4.81)	3.55* (0.3)	0.22* (0.04)	16.66* (4.52)	1.54 (0.23)	0.14 (0.04)	12.19 (5.38)	1.29 (0.18)	0.11 (0.03)	12.47 (4.79)
Change composition	55.72 (3.5)	1.45 (0.37)	40.73 (11.28)	46.46 (6.52)	1.52 (0.29)	31.49 (7.16)	4.43 (0.27)	0.32 (0.03)	13.60 (1.47)	2.03 (0.51)	0.18 (0.04)	11.04 (1.94)	1.43 (0.56)	0.13 (0.03)	10.27 (2.27)

a, b, c, different letters indicate significant differences between tree species edificator ($\alpha < 0.05$). Significant differences (*$\alpha < 0.05$; **$\alpha < 0.01$) for the tree species groups and type of tree species composition.

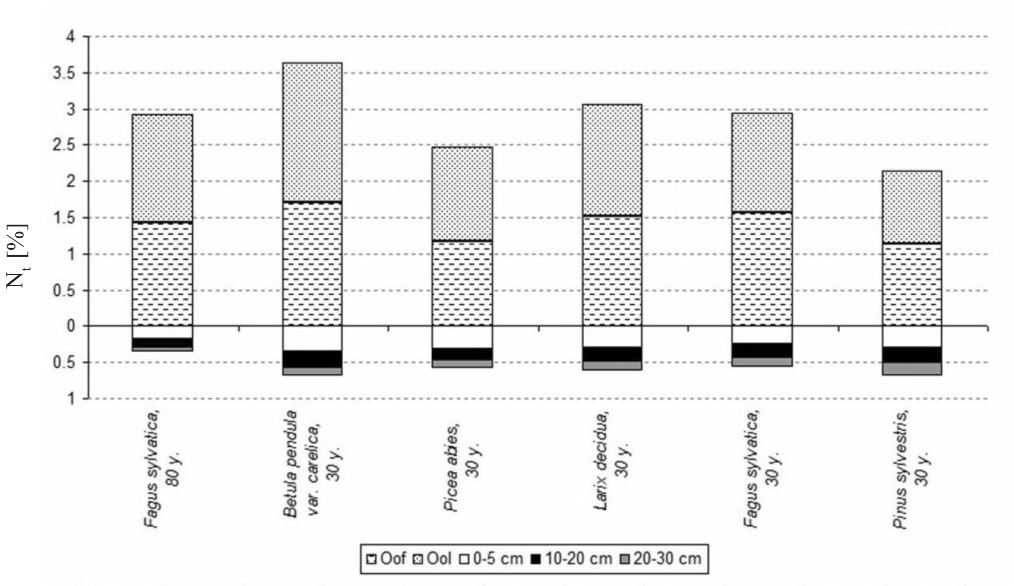

Fig. 2. Content of nitrogen in soils of studied forest stands.

birch stand; in 20–30 cm layer between mature beech and pine stand (Table 3).

Mineral layers of soils in broadleaf stands contained more nitrogen, than mineral soils in coniferous stands but differences were not significant. On average, a higher content of N_t was observed in forest stands with altered species composition, as compared to natural tree species composition, but with significant differences only in the 0–5 cm ($F_{(1,16)} = 36.280$; $p = 0.047$) layer of soils (Table 3).

C/N ratio

The C/N ratio in subhorizon Ool ranged from 24.74 (birch stand) to 54.44 (pine stand). In subhorizon Oof it ranged from 27.3 (birch stand) to 44.71 (30-year-old spruce stand) (Fig. 3). The differences between the compared phytocoenoses were statistically significant ($F_{(1,4)} = 10.12$; $p = 0.033$ (Ool); $F_{(1,4)} = 19.68$; $p = 0.011$ (Oof)). In subhorizon Oof, significant differences were found in case of natural beech phytocoenosis opposite of 30-year-old spruce stand. The lower C/N ratio in humus horizons (Oo) was found in broadleaf forest stands. Based on the results, we can conclude, that higher C/N ratio was observed in subhorizonte Ool in the forest stands with altered tree species composition, in the case of subhorizonts Oof in the stands with natural tree species composition (Table 3). However, these differences were not statistically significant.

More significant differences in the C/N ratios were found in the 0–5 cm layer of soils, where the values ranged from 12.25 (30-year-old birch stand) to 4.20 (adult beech phytocoenosis). In the 10–20 cm and 20–30 cm layers of mineral soils, the highest ratio was found in adult beech stand (16.22, respectively 15.7), the lowest in the 30-year-old beech pole stage (8.14, respectively 8.69), Fig. 3. Differences between C/N ratio of adult beech stand (in layers 0–5 and 10–20 cm) were statistically significant opposite birch, spruce, pine and young beech stand. In the layers of 10–20 cm and 20–30 cm significant differences were found in the case of adult stand opposite spruce stand (Table 3).

In the mineral soil layers of broadleaf stands, slightly higher C/N ratio was found, than in the mineral soils of coniferous stands but differences between groups of tree species were not statistically significant. The stands with changed tree species composition showed lower C/N ratio in the soil layers but differences were statistically significant only in the case of 0–5 cm layer ($F_{(1,16)} = 4.718$; $p = 0.049$).

Discussion

Woody tree species are considered to be one of the important factors that influence individual components of the ecosystems (Wulf and Naaf, 2009). Hüttl and Schaaf (1995) state that the supply of nutrients in forest soils is affected by many forest-silvicultural activities and other influences, such as the choice of edificator tree species, biomass removal, historic use of forest stands, change of tree species composition and finally acidic and nitrogen depositions. Based on our results, we can conclude that the 30-year-old stands of spruce, pine, larch, birch and beech growing on sites of natural beech stands had a partial influence on the content of carbon and nitrogen in surface humus and mineral soil layers. The same results were also concluded by the

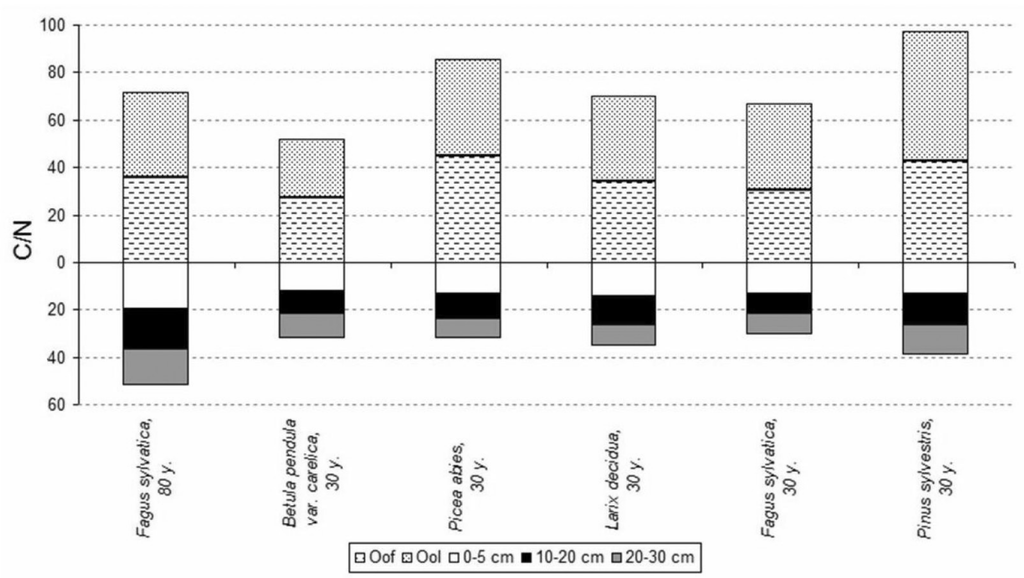

Fig. 3. C : N ratio in soils of studied forest stands.

authors Vesterdal et al. (2008), who observed effect of six European tree species on C_t and N_t contents in forest soils. Binkley and Valentine (1991) state that the chemical properties of soils can change after 50 years of growing stands, which confirms work of Fischer et al. (2002), too. The authors observed differences in soil properties between stands of different tree species at the age of 60 years. Hagen-Thorn et al. (2004) investigated the impact of six European tree species on the chemistry of mineral top soils in forest plantations. Authors did not confirm significant differences in carbon contents between the studied species after 40 years of their cultivation.

Effect of change of tree species edificator in Kremnické vrchy Mts was the most significant in the layers of surface humus and topsoil 0–5 cm, suchlike conclusions were confirmed in the work by Augusto et al. (2002), too. The changes mainly concern to increased accumulation of C_t in soil layers of coniferous stands – European larch (*Larix decidua*), Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*). Gärdenäs (1998) in his work also indicates higher stock of soil carbon in spruce and pine stand in comparison with deciduous stands. Similar results reached Vesterdal and Rasmunssen (1998); Fischer et al. (2002); Augusto et al. (2002) and Schulp et al. (2008). The highest carbon content in studied stands of Kremnické vrchy Mts was recorded in surface humus, and its contents towards the depth of the soil profiles decreased, which was probably related with the gradual release of nutrients during decomposition processes. Similar results are reported in the works by Labudová et al. (2009); Menšík et al. (2009) and Lesná and Kulhavý (2003).

Growing of non-native forest stands of different tree species edificators in the Kremnické vrchy Mts had a statistically significant impact on carbon contents in surface humus and 0–5 cm mineral soil layers. In sites with altered tree species composition, a higher accumulation of C_t, was observed than in natural beech stand. Kreutzer (1989) in their work evaluated changes in soil properties caused by growing two generations of Norway spruce on a site before formed with *Quercus* and *Tilia* species. Growing of spruce stands caused increased accumulation of C in the soil profile to 1 m depth.

Effect of tree species edificators on nitrogen content was confirmed in the 0–5 cm mineral soil layers, where statistically significant differences were found out. The highest amount of nitrogen was observed in the surface humus of studied soils, and contents towards the depth of soil profiles decreased, which was similar as in the case of C_t.

Sýkora (2011) indicated in soil layers of successional stages of beech stands a decreasing trend of biogenic elements towards the depth of the soil profiles, too. Similar results were observed by Berger et al. (2002). Lesná and Kulhavý (2003) found higher N content in subhorizon Oof, in comparison with Ool. In lower subhorizons authors observed a decrease of nitrogen content, which is in agreement with our results. Rey et al. (2008) and Sýkora (2011) found out a decrease in the nitrogen content from 0–5 cm soil layer to 10–20 cm layer of almost 50 %.

The highest significant differences in nitrogen content were found in surface humus of deciduous stands compared to the coniferous. In the mineral soil layers, higher N_t contents were reported in the coniferous stands. The results found in Kremnické vrchy Mts are consistent with findings of Lesná and Kulhavý (2003), who found higher nitrogen content in surface humus of deciduous stands, in mineral soils in coniferous stands. On the other hand, Klemmendson (1987) in his work indicated insignificant differences in concentrations of soil nitrogen between coniferous and deciduous stands, significant differences were only observed in its vertical distribution.

The total nitrogen content in the surface humus and mineral soils of studied geobiocenoses in Kremnické vrchy Mts formed following order: pine stand < spruce stand < beech forest < larch stand < birch stand. Šály (1978) in his work indicated the following order of N content in litter fall: pine < larch < birch < spruce < beech. For example, Ranger et al. (1994) found that litter fall of *Fagus sylvatica* species has approximately about 12% higher content of nitrogen in comparison with litter of *Pinus sylvestris* species. In comparison with our results, this difference was even slightly higher.

Higher N_t content in soil samples was found in the stands of changed tree species composition in comparison with the sites with natural beech composition. A statistically significant difference was found only in the 0–5 cm layer of mineral soil. Kreutzer (1989) also observed significant differences in concentrations of N in soil samples, when on the sites with changed tree species composition, higher N contents were found in the humus layers and the lower in the upper mineral soil layers (0–50 cm).

The C/N ratio is considered to be one of the main factors controlling decomposition rate of soil organic matter (Cote et al., 2000). In surface humus of studied soils, a higher C/N ratio was found in the coniferous stands (45.2), compared with deciduous (32.07). Based on the results from Kremnické vrchy Mts, ratios C/N in litterfall of analyzed stands formed following order: birch < beech < larch < spruce < pine. Wittich (1952) in his work indicates the following order: birch < beech < spruce < pine < larch. Bublinec (1994) evaluated the effect of litterfall beech, oak and hornbeam tree species. Based on his results, beech belongs among tree species with the most unfavourable effect on litterfall decomposition.

The ratios of C/N in mineral soil layers in Kremnické vrchy Mts decreased downwards in the soil profiles. Similar results were confirmed by Lesná and Kulhavý (2003). The highest ratio was found in a group of deciduous stands, but without statistically significant differences.

In the European forest soils C/N ratio ranges from 10 to 100. The C/N in organic horizons ranges between 20 and 40, in mineral horizons from 10 to 30. In Kremnické vrchy Mts, the ratio C/N in organic horizons ranged from 24.73 (birch stand) to 54.44 (pine stand). In the mineral horizons values varied from 8.14 (30-year-old beech stand) to 4.20 (80–100-year-old beech forest). Emmett et al. (1998) in his work indicates value 24 as the critical C/N ratio for coniferous stands, when at the ratio >24 less than 10% of nitrogen is washed out from ecosystem. At the C/N ratio < 24, more than 10% of total nitrogen is washed out from ecosystem. Šály (1978) states, that the ratio C/N higher than 30 leads to slow decomposition, which is reflected in the slow release of nutrients, secondary impoverishment and subsequent soil degradation (Lesná and Kulhavý, 2003). According to Warring and Rumming (1998) net mineralization occurs at C/N ratio lower than 20 and net immobilization at value higher than 30.

Conclusion

The research results showed that change of tree species composition on the sites of natural occurrence of beech had a partial influence on the content of C_t and N_t in the surface humus and mineral soil layers, after three decades of their planting. It was reflected the most in the surface humus and topsoil 0–5 cm layers. This concerned mainly C_t contents while N_t contents did not show so many significant differences between the compared stands. The highest amounts of carbon and nitrogen were recorded in the surface humus of the studied stands. These contents towards the depth of the soil profiles decreased. The highest C_t content was found in surface humus of coniferous stands; in the case of N_t it was in deciduous stands. In the mineral soil layers significantly higher contents of C_t and N_t were found in the coniferous stands, in comparison with deciduous ones. Stands with changed tree species composition showed a higher content of elements in surface humus as well as in mineral soil layers. C/N ratio in the surface humus was higher and statistically significant in the case of coniferous stands in comparison with deciduous stands. In the mineral soils higher C/N ratio was found in the deciduous stands compared with coniferous stands. The difference between compared groups of stands was insignificant.

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