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CARBON, NITROGEN, C/N RATIO AND THEIR STAND HETEROGENEITY IN THE SOIL OF NORWAY SPRUCE STANDS

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Abstract

VRANOVÁ, V., HOLÍK, L., ROHLÍK, T., REJŠEK, K., FORMÁNEK, P.: *Carbon, nitrogen, C/N ratio and their stand heterogeneity in the soil of Norway spruce stands.* Acta univ. agric. et silvic. Mendel. Brun., 2010, LVIII, No. 5, pp. 413–416

This work is aimed to determine the effect of thinning of young spruce stands in Moravian-Silesian Beskids Mts. on concentrations and relative stand heterogeneity of C_{ox}, N_t and C/N in soil. Concentrations of C_{ox} and N_t were significantly higher in individual horizons of forest humus floor. The thinning did not influence significantly ($P > 0.05$) concentrations of C_{ox}, N_t and C/N ratio in particular soil horizons, with the exception of C/N ration in E horizon. Relative stand heterogeneity of the studied soil properties was mostly higher in soil of dense forest stand. The values of relative stand heterogeneity for individual horizons ranged from 3.1 to 61.9 % in case of C_{ox}, from 4.9 to 55.2 % for N_t and from 5.3 to 42.5 % for C/N ratio. Results of this work are useful to predict stand heterogeneity of soil biochemical properties which are known to correlate with especially C_{ox} in soil on studied plots, especially soil respiration and enzymatic activities.

soil, thinning, forest, heterogeneity, carbon, nitrogen

Norway spruce (*Picea abies* [L.] Karst.) is one of the most important commercial tree species in European forests. Norway spruce is often grown in even-aged, single-species stands and managed using a clear-cutting system. Thinning is a regular component of the management program if this species is to reach the dimensions needed for the timber trade (Slodičák *et al.*, 2005). The thinning process is accompanied by a decrease in stand density and leaf area and an increase in light and nutrient availability. This leads to changes in soil temperature, soil water, regime root density, respiration of roots, leaching of dissolved organic matter from canopy, and changes in soil microorganisms (Tang *et al.*, 2005; Bird *et al.*, 2002). Thinning may reduce possible competition between plant roots and saprophytic microorganisms for water and nutrients and, in turn, enhance decomposition and nutrient cycling in these ecosystems (Slodičák *et al.*, 2005).

As thinning affects inputs of above- and belowground biomass, its decomposition and distribution in soil, it is necessary to determine its effect on change in heterogeneity of organic compounds in soil. For this reason, we have performed an experiment to determine the effect of young spruce stands thinning on stand heterogeneity of soil carbon oxidable (C_{ox}), nitrogen total (N_t) and carbon / nitrogen ratio (C/N) content in particular horizons of Typic Haplohumod.

MATERIAL AND METHODS

The "Bílý Kříž" ("White Cross") Experimental Ecological Research Site, where the experiments took place, is located in the Moravian-Silesian Beskids Mts. in the northeastern part of the Czech Republic at 908 meters a. s. l. (N 49°30'10", E 18°32'20"). The region has a subcontinental climate with a typical mean annual air temperature of 4.9°C and mean annual precipitation of 1.100 mm. The number of days with snow cover is 160 per year (Formánek *et al.*, 2008).

The experimental 23-years-old Norway spruce stand is located on slightly descending slope. The stand comprises approximately 99% Norway spruce and 1% fir (*Abies alba* Mill.). Within the experimental stand, two 0.25 ha study plots were established, each differing in intensity of thinning:

the forest dense (FD) and the forest sparse (FS) plots. The thinning of the plots was performed according to Table I. The plots are located side by side and a fence surrounds each of them. The experimental Norway spruce stand was originally established as the 2nd generative stand on an area created by clear-cutting the previous 120-years-old Norway spruce forest. Before thinning in 1995, the experimental stand was of the same initial density of 2,830 trees/ha throughout. Thinning of the FD and FS plots was then performed on a number of separate occasions as shown in Table I. Both plots were limed on three occasions (in 1983, 1985 and 1987), using dolomite limestone with a total application rate of 9 t/ha (3 × 3 t/ha) (Formánek *et al.*, 2008). In comparison with the FD plot, the FS plot has a relatively rich herb layer with grasses, shrubs, rowan seedlings, etc. Both plots maintain Typic Haplohumod (sequence horizons: Oi-Oa-Oe-A-E-Bhs-Bs-BC-C) and Entic Haplorthod (sequence horizons: Oi-Oa-Oe-A-Bsw-BC-C) soil types and subtypes (USDA-NRCS, 1999).

Experiments were restricted to only one of the two soil types on both stands: Typic Haplohumod. On each of the forest stands, five holes (15 × 15 × 70 cm) were randomly dug in period of October 6–7, 2005. Soil samples were taken from horizons Oi-Oa-Oe-A-E-Bhs-Bs, and placed into plastic bags. After transportation to the laboratory, the samples were air-dried at room temperature and consequently, except Oi and Oa horizons, sieved through 2 mm mesh size. The samples were milled using Mixer Mill MM 200 (Retsch, Germany).

The content of carbon and nitrogen was measured using NC 2100 Soil Analyzer ThermoQuest (Italia S.p.A., Italy). Soil was completely oxidized by combustion, and organic nitrogen was converted into elemental nitrogen and carbon into carbon dioxide. The gas mixture was then separated on a gas chromatographic column and measured using a thermoconductivity detector (TCD).

As preconditions for parametric statistical testing were not fulfilled, the nonparametric Kruskal-Wallis ANOVA and Dannet's *t*-test were used. All statistical analyses were undertaken using the Statistica 9.0 program (StatSoft, Inc. Tulsa, USA). Coefficients of Variation (CV) for particular soil properties and particular horizons of each of the studied plots were calculated.

RESULTS AND DISCUSSION

From the results obtained in this study it is evident that young thinned forest stands did not influence significantly ($P > 0.05$) soil contents of C_{ox}, N_t and C/N ratio in particular horizons of Typic Haplohumod (Figure 1). C/N ratio only was significantly ($P < 0.05$) higher in FD compared to FS stand in the E horizon. Relative stand heterogeneity of the studied soil properties was mostly higher in FD than in FS plot (Table II). The reason of higher heterogeneity of measured soil properties in FD stand may be higher heterogeneity of root systems; on the other hand, differences in C/N may indicate different decomposition rate of soil organic matter, different stand nutrition (N content in needles), and different leaching of organic compounds from forest humus floor into mineral soil which is connected with different intensity of throughfall between studied stands. Different intensity of leaching from forest humus floor into mineral soil and its stand heterogeneity could also affect final heterogeneity of studied properties in particular horizons. Further research is necessary to better understand these processes.

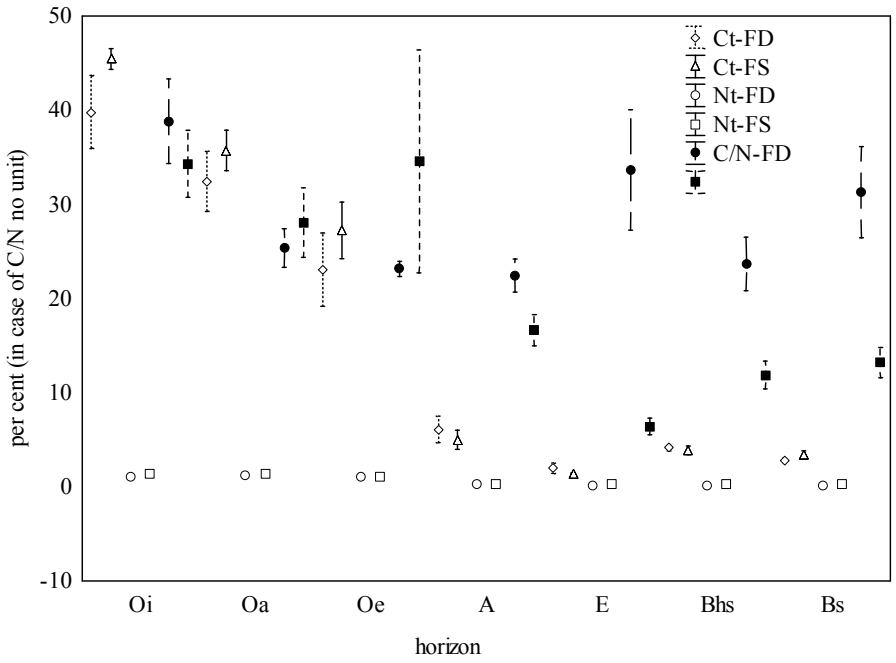
The results obtained in this work are consistent with those determined for differently managed meadows of the same locality. As reported by Vranová *et al.* (2007), about 12 years abandonment of

I: *Stand density (trees/ha) in experimental Norway spruce stands (FD-dense plot and FS-sparse plot), before and after thinning (* human – induced, in other cases stand density was reduced by natural thinning) (Formánek et al., 2008). Stand density was formed for the experimental purposes.*

year / plot	1997	1998	1999	2000	2001	2002	2003	2004	2005
FD	2600	2600	2600	2600	2600	2500	2440	2048*	2044
FS	2100*	2100	2100	2100	1880*	1820	1820	1652*	1652

II: *Relative stand heterogeneity of C_{ox} – carbon oxidable, N_t – nitrogen total and C/N – carbon nitrogen ratio calculated as Coefficient of Variation (%) in particular horizons of Typic Haplohumod of differently thinned forest stands*

Horizon	FD			FS		
	C_{ox}	N_t	C/N	C_{ox}	N_t	C/N
Oi	21.8	30.5	25.8	4.9	17.3	20.7
Oa	21.9	21.6	18.0	10.4	22.3	5.3
Oe	37. 8	39.3	7.8	22.0	51.6	19.3
A	51.7	42.1	17.5	40.9	35.9	36.9
E	61.9	55.2	42.5	3.1	36.6	35.2
Bhs	16.1	21.5	26.8	23.8	17.9	30.9
Bs	19.9	54.0	34.6	19.1	4.9	21.1



1: *Concentration of C_{ox}, N_t and C/N in horizons of Typic Haplohumod of differently thinned forest stands (n = 3-5, mean ± SE)*

previously mown mountain meadows did not significantly alter C_{ox} and N_t in particular horizons of Oxyaquic Hapludalf (classified according to USDA-NRCS, 1999). Range of relative stand heterogeneity of C_{ox}, N_t and C/N in particular horizons of both studied forest stands was not so different from that reported by Vranová *et al.* (2007) for differently managed meadows of the same locality. Contrary to our observations, the stand heterogeneity of properties determined in our study was lower compared to amino acids or mineral forms of nitrogen determined in Ap horizon of differently managed meadows of the same locality (Formánek *et al.*, 2008).

Stand heterogeneity of C_{ox} may indicate status of soil heterotrophic respiration heterogeneity on the stands. The results presented in this work are in accordance with those reported by e.g. Epron *et al.* (2004) who reported 25–50% stand heterogeneity of soil respiration in *Eucaplyptus* plantation. Other biochemical soil activities including urease or protease which are known to positively correlate with soil organic carbon may thus be predicted through their stand heterogeneity (Klose and Tabatabai, 2000; Koper and Piotrowska, 2003).

This study is useful to better understand C-cycling in Norway spruce ecosystems of different density, where other studies related to this subject (Priwitzer *et al.*, 1998; Janouš *et al.*, 2004; Pavelka *et al.*, 2007; Acosta *et al.*, 2004, 2008, Chertov, O. *et al.*, 2009) have been performed on the same plots.

SUMMARY

This work was aimed to determine the effect of thinning of young spruce stands in Moravian-Silesian Beskids Mts. on concentrations and relative stand heterogeneity of C_{ox}, N_t and C/N in soil. The experiments were performed on 23-year-old Norway spruce stand located at 908 meters a.s.l. (N 49°30'10", E 18°32'20"), on plots differing in stand density. The study was restricted on horizons Oi-Oa-Oe-A-E-Bhs-Bs of Typic Haplohumod. The thinning did not influence significantly (P>0.05) concentrations of C_{ox}, N_t and C/N ratio in particular soil horizons, with the exception of C/N ratio in E horizon. Relative stand heterogeneity of the studied properties was mostly higher in soil of dense forest stand. The reason may be higher heterogeneity of root systems and leaching of organic compounds into mineral soil connected with different intensity of throughfall. Further research is necessary to better understand these soil processes (nitrogen-carbon-soil).

SOUHRN

Uhlík, dusík, C/N a jejich stanovištní heterogenita v rozdílně obhospodařovaných smrkových porostech

Cílem této práce bylo stanovení vlivu probírky mladých smrkových porostů na koncentraci C_{ox}, N_t, poměr C/N a jejich relativní plošnou heterogenitu. Experimentální studie probíhaly ve 23letém po-

rostu smrku ztepilého(N 49°30'10", E 18°32'20", 908 m n. m.), na plochách s rozdílnou hustotou porostu. Studie byla omezena na následující horizonty, uvedené v klasifikaci USDA-NRCS z roku 1999: Oi-Oa-Oe-A-E-Bhs-Bs, kde půdním typem byl Typic Haplohumod. Probírky smrkových porostů neměly statisticky významný (P > 0,05) vliv na koncentraci C_{ox}, N_t či C/N v jednotlivých horizontech, s výjimkou C/N poměru v horizontu E. Relativní stanovištní heterogenita těchto půdních vlastností byla ve většině případů vyšší v hustší ploše. Důvodem může být vyšší heterogenita kořenových systémů a vyplavování organických sloučenin do minerální půdy, spojené s rozdílnou intenzitou podkorunových srážek. Pro hlubší porozumění procesů v půdě (dusík-uhlík-půda), je nutný další výzkum.

půda, probírka, les, heterogenita, uhlík, dusík

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