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Litterfall Carbon and Nitrogen Content of Beech Forests in Serbia

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Abstract. **This study aimed to analyze the N storage capacity of litterfall and its impact on C mineralization in beech forests. The research was conducted at 15 sample plots under European beech stands located in different ecological conditions on the territory of Serbia. More than half (53%) of the sample plots are characterized by low and very low litterfall N content (<8 g·kg^{-1}; 9–12 g·kg^{-1}), and a wide C/N ratio, which indicates a slow decomposition of the organic soil layer. These results could be useful indicators of the capacity and dynamics of litterfall N storage and its impact on C mineralization in the context of preserving biodiversity, stability, and longevity of beech forests in Serbia.**

Litterfall (organic layer) is the most important source of organic carbon (C) for forest soils. Nitrogen (N) and other nutrients are also transported to the soil from litterfall (Nordén 1994). The decomposition of litterfall plays a crucial role in the nutrient cycle of forest ecosystems. The N amount in litterfall depends on the state of nutrition of forest trees, that is, on the properties of the soil and the availability of this nutrient for plants. On the other hand, excessive N deposition results in several adverse effects on ecosystems (Berg and Matzner 1997). The C/N ratio in the organic layer is an important factor affecting N retention. In European forest soils, C/N ratios are predominantly affected by the species composition of forest stands (Cools et al. 2014).

Forests of European beech (*Fagus sylvatica* L.) occur on 10 soil types in Serbia (Knežević 2003). As a result, beech nutrition at different habitats in the country shows high spatial variability (Miletić et al. 2005). Detailed research of N content in the organic layer, depending on soil type and tree species, is significant for determining the capacity and dynamics of N storage and its impact on C mineralization, from the aspect of preserving biodiversity, stability, and longevity of forests. Bearing this in mind, the study aimed to examine how litterfall N deposition affects the N cycle and C mineralization in forest ecosystems to provide scientific information for sustainable soil management of beech forests in Serbia.

Materials and Methods

The research was conducted at 15 sample plots under pure beech stands on the territory of the Republic of Serbia (Table 1). At all sample plots, organic matter was sampled in three replications using 30 × 30 cm frames. All subhorizons of the organic soil layer were sampled as one combined sample. Samples were air-dried, and finely ground. The content of hygroscopic moisture was determined after the samples were oven-dried, at 105 °C. Sample weights of 0.2 g were separated for C and N determination following the Anstett method (Ponomareva and Plotnikova 1975). The obtained values were compared with the limit values after Vanmechelen et al. (1997).

Statistical analysis compressed numerical data for 15 beech stands (SP1–SP15), three litterfall samples (30 × 30 cm frames), and three variables (N content, C content, and C/N ratio) (15 × 3 × 3 = 135). The numerical data were processed using descriptive and univariate statistical methods. The deviation of N and C content and their ratio from the average value for all sample plots was determined by the Z-test. Determination of the difference between the average values for organic layers sampled at different altitudes and soil types was carried out using analysis of variance (ANOVA) with post hoc Fisher's least significant difference test. Statistical analyses were performed using Statgraphics (v. XVI.I, 2009; Statpoint Technologies, Inc., Warrenton, VA, USA).

Results and Discussion

The N and C content and their ratio exhibited high degrees of variability between the analyzed sample plots (CV > 20%). The N content varied from 7.10 g·kg^{-1} (SP1) to 16.70 g·kg^{-1} (SP7), with an average of 12.11 g·kg^{-1}; the C content varied from 162.80 g·kg^{-1} (SP5) to 443.30 g·kg^{-1} (SP15), with an average of 293.25 g·kg^{-1} (Table 2). Compared with data in the literature, the N and C values were similar to those obtained for the organic soil layer in Italian beech forests (Vanmechelen et al. 1997). Compared with the limit values described by Vanmechelen et al. (1997), the N values obtained for eight sample plots in Serbia (SP1, SP3–6, SP8, SP13, and SP14) (or 53%) corresponded to the classes of very low and low N content (<8 g·kg^{-1}; 9–12 g·kg^{-1}); for six sample plots (SP2, SP9–12, and SP15) (40%) the values corresponded to the medium class of N content (13–16 g·kg^{-1}), and for one sample plot (SP7) (7%) to the class of high N values (17–20 g·kg^{-1}). On the other hand, the obtained C values corresponded to the classes of very low and low C content for eight sample plots (SP3, SP5–8, SP10, SP13, and SP14) (53%), to the medium class for six

Table 1. The analyzed sample plots of beech forests in Serbia.

Sample plot	Coordinates: Latitude	Coordinates: Longitude	Altitude (m)	Soil type
SP1	44.16402°N	19.68626°E	1,035	Dystric Cambisol
SP2	44.16806°N	21.88839°E	619	Rendzic Lepotosol
SP3	44.45697°N	21.89253°E	495	Eutric Cambisol
SP4	43.88388°N	21.28636°E	421	Dystric Cambisol
SP5	43.59282°N	20.09511°E	860	Eutric Cambisol
SP6	43.44835°N	20.09779°E	1,389	Dystric Cambisol
SP7	43.59495°N	20.49203°E	949	Dystric Cambisol
SP8	43.73720°N	21.68264°E	685	Dystric Cambisol
SP9	43.15581°N	22.26839°E	1,355	Rendzic Lepotosol
SP10	43.30870°N	20.30576°E	1,526	Dystric Cambisol
SP11	43.01413°N	21.48394°E	1,275	Dystric Lepotosol
SP12	42.85967°N	22.26649°E	1,286	Dystric Cambisol
SP13	42.57848°N	22.06603°E	868	Eutric Cambisol
SP14	42.80030°N	21.91783°E	915	Luvisol
SP15	44.09717°N	21.83709°E	1,145	Dystric Cambisol

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Table 2. Descriptive statistics and *Z*-test for C and N content and their ratio in the organic layer of beech forests at 15 sample plots in Serbia.

Sample plot	N content Avg ($g \cdot kg^{-1}$)	N content *Z*-value[i]	C content Avg ($g \cdot kg^{-1}$)	C content *Z*-value	C/N ratio Avg	C/N ratio *Z*-value
SP1	7.10	**1.85**	308.90	−0.24	43.40	**−2.84**
SP2	14.20	−0.77	368.90	−1.18	25.90	−0.15
SP3	8.10	1.48	209.40	1.30	25.80	−0.14
SP4	11.60	0.19	302.70	−0.15	26.00	−0.17
SP5	9.90	0.82	162.80	**2.03**	16.40	1.31
SP6	11.40	0.26	280.50	0.20	24.70	0.03
SP7	16.70	**−1.70**	280.10	0.20	16.80	1.25
SP8	11.80	0.12	288.10	0.08	24.40	0.08
SP9	14.90	−1.03	305.90	−0.20	20.50	0.68
SP10	14.20	−0.77	286.80	0.10	20.10	0.74
SP11	13.70	−0.59	314.50	−0.33	22.90	0.31
SP12	14.30	−0.81	333.20	−0.62	23.30	0.25
SP13	9.80	0.86	251.10	0.66	25.60	−0.11
SP14	10.40	0.63	262.50	0.48	25.30	−0.06
SP15	13.60	−0.55	443.30	**−2.33**	32.60	−1.18
Avg	12.11		293.25		24.91	
SD	2.70		64.34		6.50	
Coefficient of variation	22.32		21.94		26.11	
Minimum	7.10		162.80		16.40	
Maximum	16.70		443.30		43.40	
Range	9.60		280.50		27.00	

[i] Bold values denote sample plots with *Z*-values that are approximately ≥2 *SD* higher or lower than the average.

sample plots (SP1, SP2, SP4, SP9, SP11, and SP12) (40%), and to the high class for one sample plot (SP15) (7%). The C/N varied from 16.40 (SP5) to 43.40 (SP1), with an average of 24.91. In the case of wide C/N ratios, the decomposition of organic matter is slowed down, whereas a narrow C/N ratio indicates rapid decomposition of organic matter and efficient translation of plant nutrients into mineral form available for plants (Kadović et al. 2012). Therefore, it can be argued that at sample plots with a narrow C/N ratio, a nutrient-rich mull humus was formed, representing an important source of minerals for plants and having a favorable effect on soil properties.

Based on the *Z*-test, N contents determined in the organic layers at SP1 and SP7 were significantly different compared with the contents determined for other sample plots. The same applies to the C contents for SP5 and SP15 and the C/N ratio for SP1 (Table 2). Considering the obtained N values for the investigated sample plots, the sensitivity of the ground flora to N deposition can be assessed, which is of ecological importance because it can result in changes in the composition of plant species and loss of biodiversity. On the other hand, there is an increased risk of N loss when the C/N ratios are less than 25 (MacDonald et al. 2002). ANOVA revealed that there are no statistically significant differences between the average values of N and C content, and C/N ratios in organic layers sampled at different altitudes and soil types (results not shown). The variability of N and C content in the area is probably a result of the microclimatic conditions of beech habitats, the age and structure of the stands, the composition of the organic soil layer, and the type of forest management.

These results should be considered as important information for sustainable soil management of beech forests in Serbia.

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