Some Results of Stationary Sample Plot for Intensive Monitoring of Forest Ecosystems in Vitinya Area

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Abstract

Results are presented for the chemical composition of the forest litterfall and lysimetric waters of Cambisols from the intensive monitoring stationary sample plot of the forest ecosystems. Litterfall (litter biomass fraction) had fallen on the soil surface with acid reaction, which in the period 2011 - 2018 varied from 5.1 to 5.4. The established contents of calcium (6.9 $mg.g^{-1}$), magnesium (0.52 $mg.g^{-1}$), potassium (3.58 $mg.g^{-1}$), nitrogen (7.28 $mg.g^{-1}$) and phosphorus (0.55 $mg.g^{-1}$) were low and those of manganese (1754 $\mu g.g^{-1}$), iron (185 $\mu g.g^{-1}$), copper (11 $\mu g.g^{-1}$) and zinc (36 $\mu g.g^{-1}$) were high. The lysimetric waters in the surface horizon were very strongly acidic – pH_{H2O}= 4.6. The amounts of all the tested parameters in them were very low – dissolved organic matter (8.0 $mg.dm^3$), potassium (2.6 $mg.dm^3$), calcium (5.7 $mg.dm^3$) and others. Only the content of manganese was increased, which in some years exceeded the maximum value pointed in the literature for the European forests. It is assumed that degradation processes take place in the mineral part of the soil which lead to its impoverishment of macro and microelements.

Key words: litterfall, lysimetric waters, common beech, Cambisols

Introduction

In the forest ecosystems, nutrients make internal circulations along the 'entrance and exit' paths in them. The entrance is implemented through the litterfall, wet and dry depositions, stemflow, and the exit - through cuttings, lysimetric waters, etc. (Smidt et al., 2012). Their behavior inside the soil depending on its reaction, adsorption surfaces, and others. The results of the impact of anthropogenic activity are evaluated by the displacement of the basic cations from the litter (L) and the soil, the occurrence of calcium and magnesium deficiency in the leaves of tree species, and others (Kiikkilä, 2003).

The main sources of nutrients for the soil are litterfall and weathering processes. Litterfall becomes very important when in the soil-plant system the biological cycle dominates over the geochemical one. According to Legout et al. (2014) in rich soils, nutrient amounts are result of weathering processes, i.e. from the dominance of the geochemical circle. However, the intensity of weathering is determined by the climatic conditions, and for the mountainous territories in the country they are most often characterized as “harsh”.

Litterfall accumulates on the soil surface where it forms the litter. It is considered to be the most dynamic and rapid flow of nutrients to soil in forest ecosystems. Litterfall is an important source not only of nutrients but also of organic carbon for the soil (Sayer, 2006). It has been considered by some authors as a key component in assessing soil organic matter retention in global warming conditions (Liski et al., 2005; Hansen et al., 2009).

The aim of the study was to evaluate the amounts of nutrients in the litterfall and lysimetric waters in the intensive monitoring stationary sample plot in Vitinya area, obtained for 2018 and their dynamics in the period 2011 - 2018.

Materials and Methods

Vitinya stationary sample plot is located in the western part of the Central Balkan Mountains, on the territory of Vitinya State Forestry. It was selected as representative of the natural beech (*Fagus sylvatica* L.) forests in the country (Kolarov et al., 2002). The altitude is 950 m. It is located in the Mountain Climate Region, Middle Mountain Subarea (Koleva - Lizama, 2002). The soil is Dystric Cambisols, formed on gneiss.

Litterfall was collected in 5 pcs. catchers, each with an area of 1 m^2. It was collected every two weeks, separating in 3 major fractions according to the Methodological Monitoring Manual, Part 15 (ICP Forests, 2006). The fractions were as follows: litter (L), wood fraction (WF), which includes bark, branches, twigs and others with area exceeding 5 x 5 mm or with diameter more than 2 mm, and fruits and seeds (FS).

Eight sites were created to collect lysimetric waters, from which mixed samples were made. The lysimeters were placed at such depth so they can collect water from the surface and from the metamorphic horizons. Samples were collected every two weeks.

Sampling and laboratory analyzes of the observed parameters were carried out by the Executive Agency for the Environment towards Ministry of Environment and Waters in connection with the implementation of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) – Level II, within the framework of the Convention on Long-range Transboundary Air Pollution of the United Nations Economic Commission for Europe.

Results and Discussion

The total biomass of litterfall was observed for a longer period (2009 - 2018) than other indicators, and it varied significantly (Fig. 1). The most stable was the biomass of the L fraction. The other 2 fractions - WF and FS were characterized by large variation due to the different amounts of bark, twigs, reproductive organs, and others that fall into the catchers. Fraction WF may even be absent. Also important was the fruiting of the common beech, which is not annual.

Table 1. Contents of macro- and microelements in litterfall from Vitinya Stationary sample plot, 2018.

Catcher №	Fraction	pH $_{H2O}$	N	S	P	Ca	Mg	K	org.C	Zn	Mn	Fe	Cu	Pb	Cd
			mg/g						g/100g	µg/g					ng/g
1	Litter	5.36	7.95	0.99	0.55	4.29	0.69	4.91	47.82	26.76	2867.8	180.78	7.24	0.79	198.22
2		5.48	5.63	0.86	0.31	9.06	0.28	1.15	47.87	44.20	911.7	135.53	13.75	2.09	392.91
3		5.60	8.25	0.75	0.94		0.59	6.06	48.20	12.02	714.2	124.27	9.97	0.59	195.40
4		5.37	7.50	0.85	0.52	4.47	0.73	4.55	48.11	27.28	3138.7	214.73	6.13	0.59	197.00
5		5.38	7.09	0.94	0.46	9.80	0.36	1.27	48.32	72.38	1142.4	270.04	16.16	9.11	489.69
mean		**5.43**	**7.28**	**0.88**	**0.55**	**6.90**	**0.52**	**3.58**	**48.06**	**36.52**	**1754.95**	**185.07**	**10.64**	**2.63**	**294.64**
st.dev		*0.10*	*1.02*	*0.09*	*0.23*	*2.92*	*0.20*	*2.24*	*0.21*	*23.05*	*1153.55*	*56.72*	*4.25*	*3.67*	*138.12*
1	Wood Fraction	5.55	10.06	0.85	1.10		0.54	6.02	47.20	13.09	919.0	94.24	9.70	0.39	193.92
2		5.35	8.66	0.89	0.59	4.82	0.76	4.71	47.17	29.04	2934.2	285.81	8.86	0.98	196.89
3		5.3	6.13	0.87	0.51	4.79	0.29	1.17	46.92	41.84	811.6	151.94	11.53	10.56	387.42
4		5.43	10.07	0.79	1.04		0.74	6.28	47.49	15.70	1004.3	101.54	10.69	0.39	192.68
5		5.33	7.92	1.07	0.38	4.96	0.79	4.82	41.98	31.96	3008.0	197.92	7.86	0.70	199.11
mean		**5.39**	**8.57**	**0.98**	**0.72**	**4.85**	**0.62**	**4.59**	**46.15**	**26.38**	**1735.38**	**166.29**	**9.72**	**2.60**	**234.00**
st.dev		*0.10*	*1.64*	*0.10*	*0.32*	*0.09*	*0.21*	*2.04*	*2.34*	*11.91*	*1130.37*	*78.85*	*1.44*	*4.45*	*85.80*
1	Fruits and Seeds	5.25	7.26	0.94	0.34	8.26	0.32	1.42	47.88	49.54	937.0	178.49	15.99	8.44	490.46
2		5.37	5.28	0.75	0.60		0.40	6.51	45.56	12.62	600.60	91.88	7.51	0.29	192.62
3		5.23	11.07	0.96	0.58	4.44	0.91	4.45	46.35	30.09	2582.01	221.34	10.89	0.89	197.98
4		5.31	5.98	0.92	0.29	6.97	0.36	1.52	46.74	41.07	833.75	169.55	12.01	5.23	387.48
5		5.29	7.13	0.79	0.71		0.44	7.20	46.49	9.18	655.95	69.66	8.50	0.49	195.40
mean		**5.02**	**7.60**	**0.92**	**0.81**	**18.62**	**1.31**	**4.83**	**53.47**	**34.72**	**885**	**413**	**7.11**	**2.72**	**236.52**
st.dev		*0.08*	*0.82*	*0.04*	*0.02*	*2.10*	*0.14*	*0.40*	*0.70*	*6.74*	*252*	*399*	*0.74*	*0.50*	*46.93*

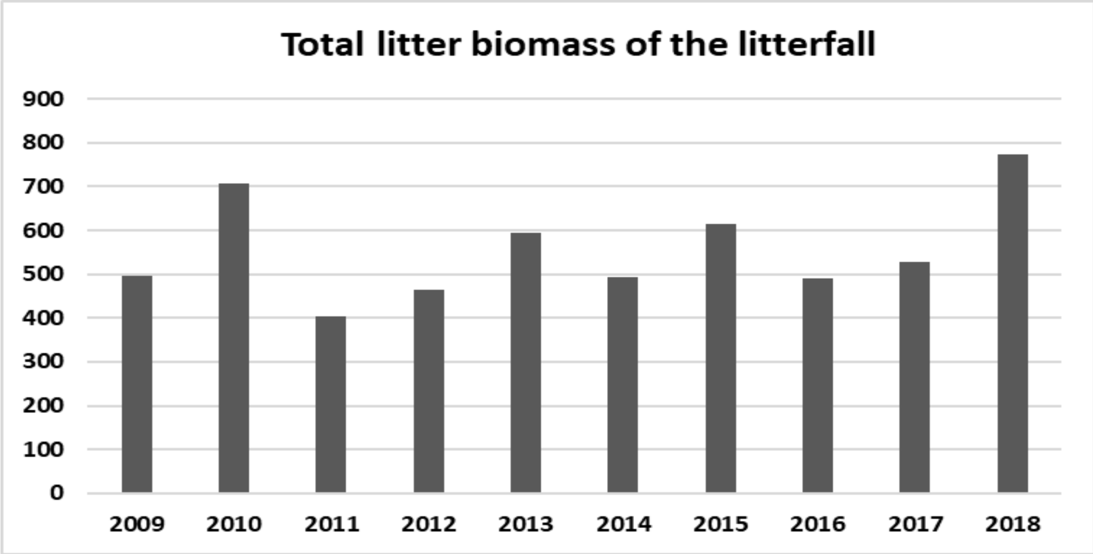
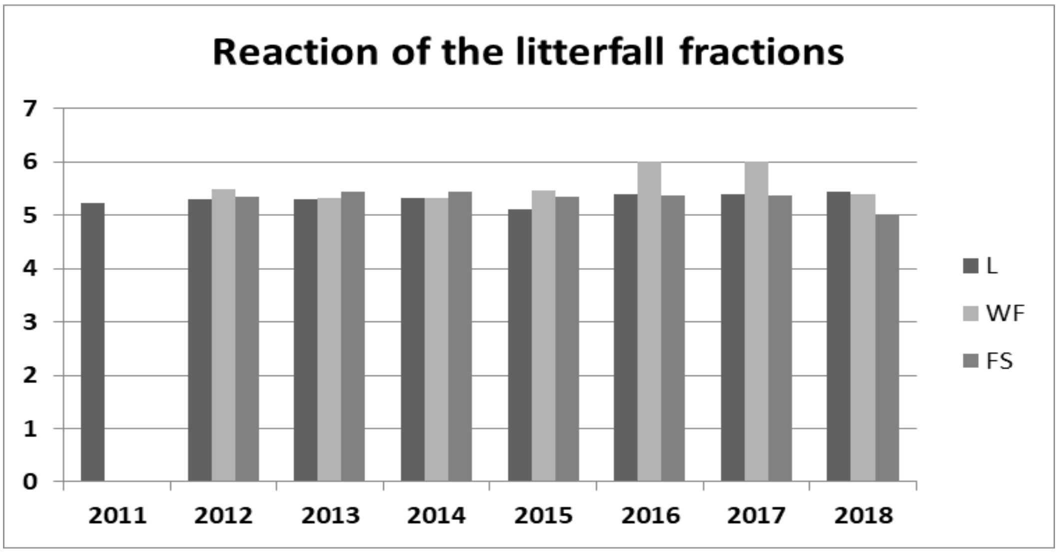


Fig. 1. *Total litter biomass of the litterfall for the period 2009-2018 (g/m^2)*

The maximum leaf fall was in the range of 1 month – October, but there were also periods of smooth flow of this process – for 2 months, mainly October and November. Fraction WF was forming more active at the beginning of the vegetation season – April, and in its end – October. For the FS faction, this period was in September–October.

Table 1 presents the litterfall reaction and the content of macro- and microelements by fractions. The reaction of litterfall was in the acid spectrum. For the L fraction, values close to those of previous years were obtained in 2018 (Fig. 2). An exception was found in 2015 as the results differ sharply. The lowest pH value was then obtained, with a statistically significant difference compared to 2013 (p = 0.014) and 2014 (p = 0.014).

Significant differences in the reaction of fraction WF - in 2016 and 2017 were established. They were not confirmed in time. It can be assumed that they were with incidental origin.

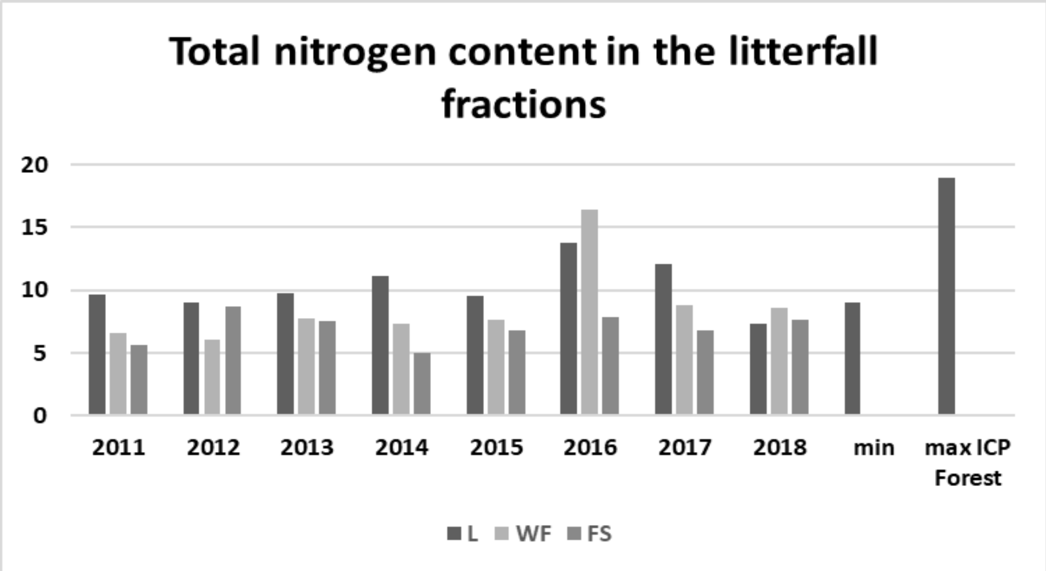


L –Litter. WF-Wood fraction. FS– Fruits and seeds

Fig. 2. *Reaction of the litterfall fractions for the period of 2011-2018.*

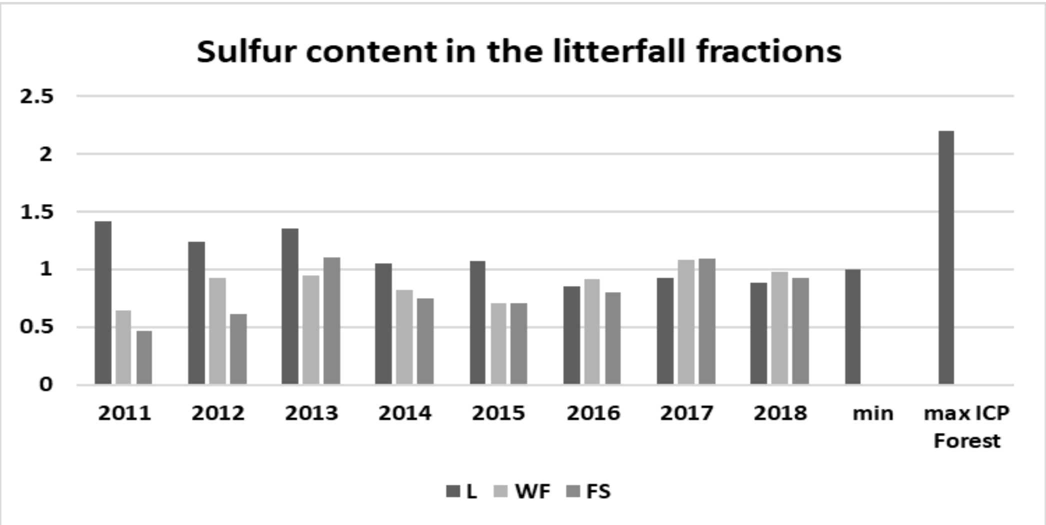
The nitrogen content of litterfall for the period 2011 – 2015 was low, close to the minimum value specified in the criteria of the ICP Forests Guide (2016). Higher values were reported in 2016 and in particular in 2017 (Fig. 3). In 2018, the tendency for lower nitrogen content in litterfall was reversed.

Regarding the amount of phosphorus, it can be said that its return to the soil through the litterfall was slightly higher than the minimum value specified in ICP Forests Guide Part 15 (2016), which was satisfactory.



L –Litter. WF-Wood fraction. FS– Fruits and seeds

Fig. 3. *Total nitrogen content (mg.g^{-1}) in litterfall fractions for the period of 2011 -2018 and ICP Forest criteria.*



L –Litter. WF-Wood fraction. FS– Fruits and seeds

Fig. 4. *Sulfer content* (mg.g^{-1}) *in litterfall fractions for the period of 2011-2018 and ICP Forest criteria*

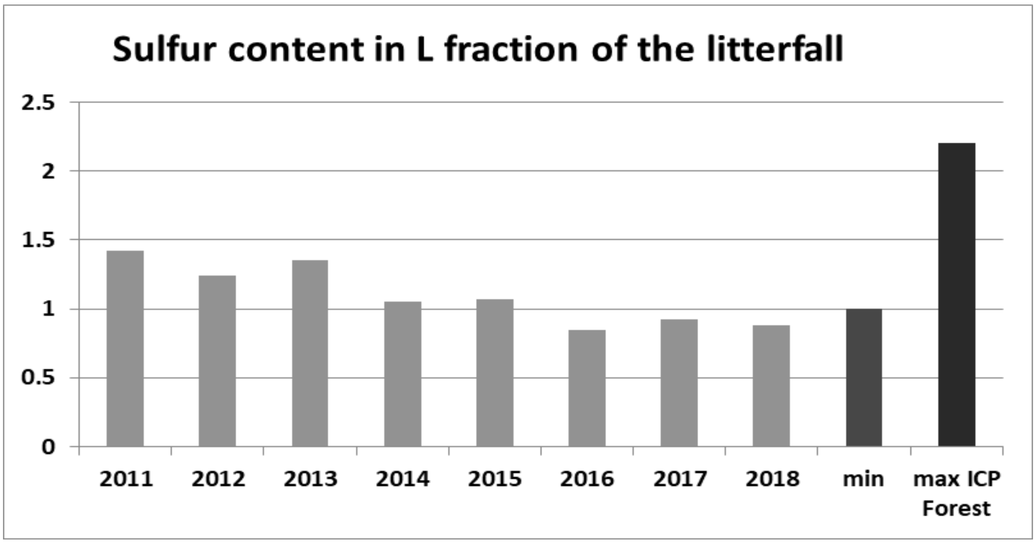


Fig. 5. *Sulfur content (mg.g^{-1}) in „Litter" fraction in litterfall for the period of 2011-2018 and ICP Forest criteria.*

The sulfur content continued to show a decreasing trend. In previous years, even lower concentrations were measured than those obtained in 2018 (Fig. 4). All results were below the minimum pointed out in ICP Forests Guide Part 15 (2016). This was most relevant for the L fraction (Fig. 5).

The calcium and magnesium macronutrients in the L fraction were low throughout the observation period. These of potassium also, as they varied around the minimum value. Given that this fraction (L) was the main source of organic matter for the soil, it could be assessed that the input quantities of basic elements were low.

The results showed a lasting tendency for an increased amount of microelements – manganese, iron, copper and zinc. As in previous years, they were high. This is most pronounced for the more mobile elements especially for manganese (Fig. 6) and copper which were observed from 2009 to 2018 (Fig. 7), but for the manganese there was a lack of data for 2017 and 2018.

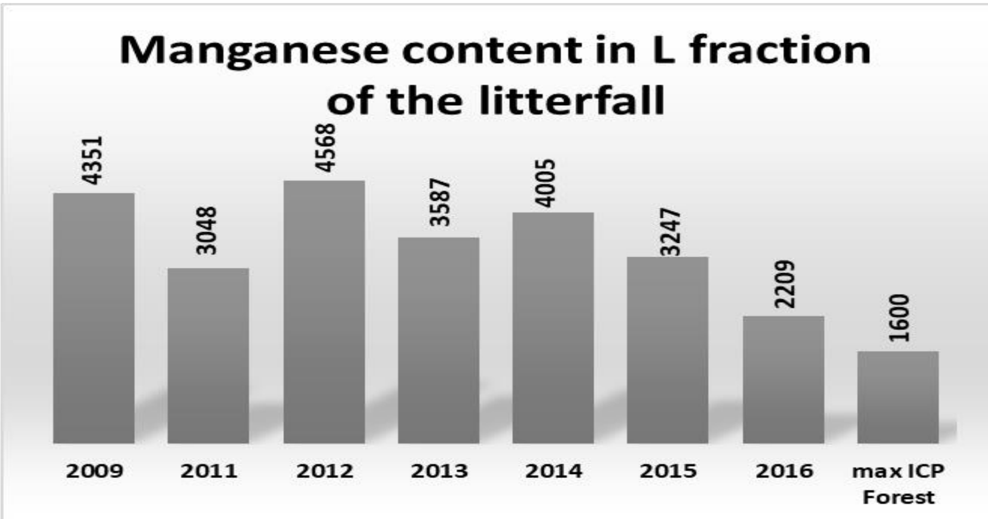


Fig. 6. *Manganese content (µg.g^{-1}) in „Litter" fraction in litterfall for the period of 2009-2018 and ICP Forest criteria*

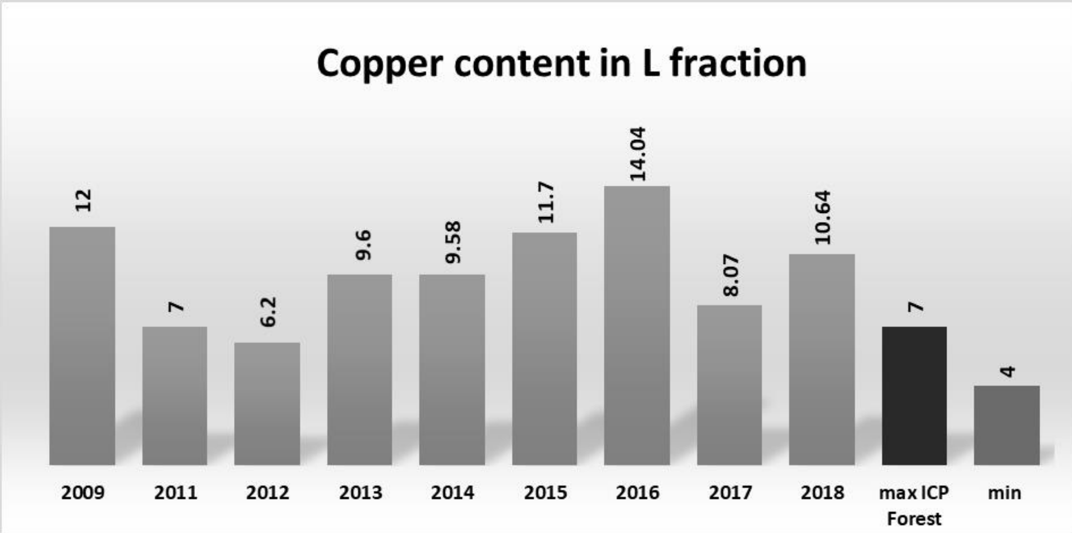


Fig. 7. *Copper content (µg.g^{-1}) in „Litter" fraction of litterfall for the period of 2009-2018 and ICP Forests criteria.*

Lead and cadmium values in 2018 varied more than in previous years. They were not assessed as high, but for both elements in the L fraction there was one high concentration obtained for at least 1 catcher. For now, it is appropriate to observe this fact because it also concerns the content of iron and zinc, which allows contamination of the samples.

Most of the studied elements were unevenly distributed in the different fractions. Usually, the L fraction accumulated higher amounts of microelements. The results of the FS fraction were strong in the direction of high accumulation of calcium, potassium, phosphorus and iron.

High amounts of microelements and low macroelements were explained by the very high soil acidity. In it occurred processes of mobilization of manganese, copper, zinc and other microelements and leaching of basic cations. The sum of the basic elements entering the soil with the litterfall is very low. It is 59 kg ha^{-1} yr $^{-1}$ (Malinova, 2014). For comparison with the other 2 stationaries for intensive monitoring, this amount was 139 kg ha^{-1} yr $^{-1}$ in Hungarian oak (*Quercus frainetto* Ten.) stand (Staro Oryahovo stationary sample plot) and from European spruce (*Picea abies* (L.) Karst) from - 95 kg ha^{-1} yr $^{-1}$ (Yundola stationary sample plot). The difference with common beech came mainly from calcium and potassium, which were low in beech litterfall.

The measured reaction of lysimetric waters is an indicator of the presence of free carbonic acid in the soil, as well as of organic acids of biogenic origin, which are the result of the dominant influence of acidic products in the soil formation process. It varies slightly over time (Fig. 8).

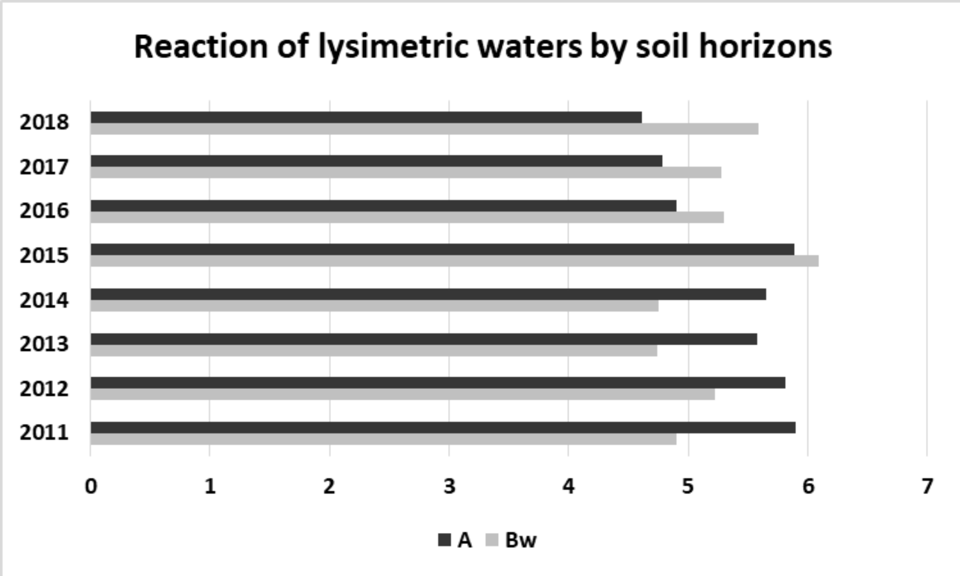


Fig. 8. *Average pH values of lysimetric waters for the period 2011-2018*

The alkalinity was low, which means that the neutralizing ability of the lysimetric waters was too low (Table 2). In some years, higher values were obtained - up to 265 µmolc/l, which is also not high compared to the indicated minimum and maximum limits in the ICP Forests Guide. The conductivity of the solution was very low. It was dominated by chlorine ions, sulfates, nitrates, phosphates, ammonium ions. Base cations were also in low amounts.

Table 2. *Active reaction, electrical conductivity and ionic composition of lysimetric waters, 2018.*

Horizons	pH_{H2O}	Alkalinity	Electrical conductivity	Dissolved organic matter	K	Ca	Mg	N -NO_3	S-SO_4	N-NH_4
		µmol/l	**µS/cm**	**mg/dm^3**						
A	4.61	32	64.35	7.26	2.52	5.50	0.71	0.07	6.24	0.03
Bw	5.48	32	72.43	5.72	1.84	4.62	1.05	0.16	7.20	0.03

Table 2. (*Continued*).

Horizons	Cl	N (total)	Na	Fe	Mn	Zn	Cu	Pb	Cd
	mg/dm^3			**µg/dm^3**					
A	4.20	0.71	1.65	421.37	288.00	64.00	13.00	1.00	0.03
Bw	4.00	0.59	2.12	109.60	544.75	29.75	2.00	1.00	0.03

The manganese content was high (319 µg / dm^3 - 544 µg / dm^3) and in some cases also and iron. Manganese reached 1890 µg / dm^3 at an upper threshold of 1900 µg / dm^3 (ICP Forests Guidelines Part 11, 2016).

Conclusion

In Cambisols from the intensive monitoring stationary sample plot in the Vitinya area, there is a clear tendency for the litterfall chemical composition. Low amounts of macroelements nitrogen, phosphorus, sulfur, as well as basic elements and high amounts of microelements, mainly manganese and zinc, were returning to the soil. At the exit of the ecosystem - low amounts of water-soluble forms of the investigated macroelements, microelements, and salts were exported through lysimetric waters. It is important that forestry practices focus on limiting the export of dead biomass from the stands in order to recover the elements extracted from it through the root system of the plants.

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