Space-time patterns of soil pH and conductivity in submountain beech ecosystems in the West Carpathians

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Abstract

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In this work are summarised the results of a monitoring of pH values and conductivity which we have performed for 13 years in the localities of Kremnické vrchy Mts. The study locality, situated in the Western Carpathians Mts, was previously exposed to a moderate pollution only, and the pH values we obtained on a deforested plot in this locality were: 6.08 for precipitation water, 6.05 for the surface humus and 6.36 at a soil depth of 0.1 m. In a forest stand in the same locality we recorded 6.11 in the cover humus and then the values decreased down to 5.99 at 0.25m. The electric conductivity values showed a similar trend.

Keywords

pH, conductivity, throughfall, submountain beech forest

Introduction

The principal and the easiest at hand indicator of soil acidity is its pH and conductivity.

Acidification and eutrofication of forest soils belong to the main factors responsible for significant changes to forest ecosystem diversity in a long term prospect (Bobbink et al., 2010; Dupre et al., 2010; Maskell et al., 2010). This results in the depletion of cations providing basic nutrients necessary for production and vitality of tree layer (Fenn et al., 2006), drop in pH values and lowering the humus quality (Borůvka et al., 2005; Bonneau, 2005).

The soil vulnerability is firstly implied by the parent rock material, altitude and other basic soil forming factors (Manderscheid et al., 2000; Katutis et al., 2008). The main anthropogenic agents affecting soil acidification are acid deposition and forestry. To understand and control the factors underlying forest stand development means a very complex process, the individual constituents of which may interact in a positive or negative way. The effects of each of these factors can be multiple and simultaneous. Despite the dramatic pan-European decrease in sulphur emissions recorded in the recent decades (Kunca, 2008; Pichler et al., 2006; Jandl et al., 2012; Zapletal, 2006) the soil acidification is still remaining a serious forestry-related and environmental problem.

The drop in soil acidity and the nitrogen deposition in context of the contemporary climate change will limit the silvicultural function of forest communities. Trapping carbon and nitrogen, these communities act as an effective filter and a cleaning layer for water flowing through them. Storing and accumulation of nitrogen in soil can mitigate negative impacts of the climate change.

The aim of this paper was to show the trends in pH and conductivity values in the beech stand and open plot in the Kremnické vrchy Mts (the West Carpathians Mts).

Methods

The research plots (RP) are situated in the Kremnické vrchy Mts (48°38´ N, 19°04´ E), in the central part of the West Carpathians Mts. The leading, high dominant forest woody plant is beech, the stand age is 90–100 years, the average tree height is 28 m. The site is at 450–510 m asl, on a slope with an inclination of 17–20° (Barna, 2008; Kellerová, 2006). The site climate is moderate warm, hilly district B5 with an average annual temperature $t_{1951–1980}$ of 6.8 °C and an average annual precipitation total of 778 mm (Schieber, 2006).

The mean annual precipitation total in the growing season is 395 mm, the growing season length is 115–165 days.

The prevailing soil forming substrate consists of andesite tuff agglomerates from which there has been formed a saturated variant of cambisol andosolic with skeleton content increasing with the depth. The soil body is layered, composed of the main and the basal layer system (Pichler, 2006; Pichler et al., 2009; Kukla, 2002).

The lysimetric water was sampled into plastic collectors (1,000 cm^2) in three different soil horizons. The first set is installed in the layer H_{oo}, i.e. the surface horizon (organic layer), the second at a depth of 0.10 m below the soil surface (upper mineral layer) and the third at 0.25 m below the surface (lower mineral layer) (Kukla, 2002).

Atmospheric precipitation and throughfall water were collected into funnels issuing in closed collectors (660 cm^2). The collectors were spaced regularly throughout the beech stand and the adjacent open plot (by 10 pcs on each). The representative samples were obtained by mixing the water from all collectors in the forest stands and open plots. In both cases, the samples were collected at regular time intervals (per month for 13 years) and after each relevant precipitation episode (Lindberg and Turner, 1988).

Results and discussion

The mean annual pH value obtained over the study period on the forested plot was 6.1. The maximum representing 6.49 was recorded in 2001, the minimum of 5.37 was in 2003. The variability was very low and the overall trend was decreasing.

The mean pH value of soil solution at 0.1 m was 6.18, with a maximum of 6.55 recorded in 2012, and a minimum of 5.81 recorded in 2009. The coefficient of variation was only 1.12% (Table 1). The pH value of water percolated through surface humus may be lower (reported from the localities Želivka and Rájec in the Czech Republic, Lochman, 1997) or somewhat higher (documented in south England, Gower et al., 1995), than the original pH value on the surface. As far we know, the highest pH increase in the water percolated

Table 1. Descriptive statistics of pH and conductivity in the Kremnické vrchy (Western Carpathians Mts.) in years 2000–2012

Lysimeter	K_{00}	K_{10}	K_{25}	Forest throughfall	H_{00}	H_{10}	H_{25}	Open plot wet deposition
				pH				
Mean	6.11	6.18	5.99	5.77	6.05	6.36	6.33	6.08
Min	5.37	5.81	4.89	5.40	5.72	5.92	5.66	5.59
Max	6.49	6.55	6.80	6.32	6.35	6.81	6.77	6.61
Range	1.12	0.73	1.91	0.92	0.63	0.89	1.11	1.02
v_x %	1.30	1.12	2.50	2.96	3.62	4.38	4.58	4.90
Std. Dev.	0.31	0.25	0.57	0.32	0.22	0.28	0.29	0.31
Std. Error	0.09	0.07	0.15	0.11	0.06	0.07	0.08	0.08
				Conductivity [µS]				
Mean	101.61	64.53	78.51	76.51	88.42	80.96	72.58	78.96
Min	24.61	33.22	37.66	28.56	40.97	30.14	25.09	34.64
Max	243.37	126.64	149.93	123.11	156.95	186.28	159.96	150.34
Range	218.76	93.42	112.26	94.55	115.98	156.14	134.78	115.70
v_x %	15.52	13.06	12.52	14.23	10.65	16.19	12.97	13.13
Std. Dev.	56.88	30.39	35.47	32.66	33.95	47.27	33.93	37.96
Std. Error	15.77	8.43	9.83	10.88	9.41	13.11	9.41	10.37

v_x – coefficient of variation
K_{00}–K_{25}, lysimeter in the forest; H_{00}–H_{25}, lysimeter in the open plot.

under surface humus was observed in the locality Hukavský grúň, Poľana Mts, Slovakia (Minďáš, 2005).

The mean pH value at 0.25 m was 5.99. So, the spatial pattern of pH values looks different from the Štiavnické vrchy Mts in which pH decreased with increasing depth, and in overall the values reached were lower (according to our measurements, by 1.2 pH on average).

The mean pH value in the throughfall was 5.77, which represented the lowest value in this locality (Table 2).

The pH values and their course on the deforested plot were very similar to the ones in the forest stand – in the surface humus, and also at 0.1 m and 0.25 m below the surface (Table 1, 2). The pH values decreased with increasing depth. The opposite has been reported for lysimetric water sampled on a clear-cut plot at the locality Biely Váh (High Tatras Mts) for which Kukla (1994) obtained a pH value of 6.67 in the surface humus and 7.97 at 0.1 m. Mihálik et al. (1993) compared pH values between free precipitation and beech throughfall in the locality Mláčik in the Kremnické vrchy Mts, and they obtained (in 1990): 4.92 on open plot moderately increased to 5.29 in beech throughfall in case of old trees (130 years) and to 5.26 in case of young trees.

The pH conditions in the free precipitation in open area were found very similar to the throughfall. There has only been recorded a minute drop in pH values (by

Table 2. pH and conductivity in the Kremnické vrchy (Western Carpathians Mts) in years 2000–2012

Lysimeter Year	K_{00}	K_{10}	K_{25}	Forest throughfall	H_{00}	H_{10}	H_{25}	Open plot wet deposition
				pH				
2000	6.43	6.38	5.82	6.18	6.18	6.02	6.41	6.12
2001	6.49	6.54	6.80	6.32	6.24	6.60	6.52	5.82
2002	6.42	6.26	6.07	5.42	6.27	6.69	6.58	6.25
2003	5.37	5.95	4.89	5.58	6.05	6.12	–	5.92
2004	6.26	6.36	5.23	5.40	5.90	6.18	6.26	5.82
2005	5.92	6.16	5.28	5.81	5.74	6.09	6.22	6.38
2006	5.88	5.88	5.91	5.56	5.76	5.92	5.92	5.59
2007	6.27	5.96	6.44	–	6.20	6.81	6.77	6.61
2008	6.23	5.93	6.10	–	6.06	6.46	6.36	6.34
2009	5.87	5.81	6.01	–	5.72	6.32	6.66	6.37
2010	6.19	6.21	6.58	–	5.89	6.29	6.41	6.22
2011	5.94	6.36	6.29	5.74	6.23	6.59	6.52	5.65
2012	6.27	6.55	6.52	5.99	6.35	6.59	6.43	6.02
				Conductivity [µS]				
2000	133.79	80.92	91.38	123.11	156.95	165.13	69.60	135.67
2001	131.32	70.86	73.60	119.34	138.77	88.50	94.28	113.49
2002	97.01	66.48	87.73	82.66	91.48	79.19	64.48	79.10
2003	243.37	67.62	149.93	99.33	110.75	65.55	60.58	80.07
2004	136.53	113.53	119.83	46.05	105.30	93.05	74.59	40.88
2005	74.78	33.22	40.91	28.56	65.84	30.14	25.09	34.64
2006	72.84	42.06	53.95	60.38	61.33	51.70	40.80	46.42
2007	67.47	81.59	120.40	–	102.57	186.28	159.96	150.34
2008	125.55	126.64	90.16	–	86.53	95.08	101.05	107.73
2009	33.52	48.35	53.83	–	63.27	47.92	51.19	76.68
2010	24.61	36.77	62.27	74.65	40.97	34.69	55.22	56.46
2011	116.94	33.37	37.67	54.58	72.33	68.84	91.46	58.15
2012	63.15	37.54	38.94	32.14	53.43	46.51	55.26	46.83

K_{00}–K_{25}, lysimeter in the forest; H_{00}–H_{25}, lysimeter in the open plot.

0.03) in the forest stand. This implies that the forest had a little impact on precipitation falling through the crowns, by reducing its pH value only slightly. Minďáš (2006) speaks about a distinct change after percolation through the cover humus were the original precipitation pH values were mostly shifted from the acid or strong acid range (throughfall) to moderately acid range (statistically significant at $\alpha = 0.01$).

In comparison with the Štiavnické vrchy Mts, formerly exposed to a heavy airborne pollution load, the mean conductivity values were lower on both plots studied, and the values of this variable decreased with increasing depth: on the plot covered with forest stand from 101.61 in the surface humus to 78.51 at 0.25 m, and on the open plot from 88.42 µS in the surface humus to 72.58 µS at 0.25 m (Table 1). The two localities also show similar variability, maximum and minimum values, with lower values recorded in the Kremnické vrchy Mts in overall. Minďáš (2005) reports only statistically insignificant differences in electric conductivity between canopy gaps and throughfall in beech stands. According to the same author, spruce throughfall manifested statistically significant ($\alpha = 0.01$) changes and also more amplitude in electric conductivity – an indicator of overall mineralization. Even more amplitudes can occur after percolation through the surface humus layer. In this case the difference against the free precipitation above the stand was statistically significant ($\alpha = 0.01$), analogically as in the case of lysimetric water in the mineral soil layer.

Conclusion

The accumulative trend of acidifying components of forest soils downwards the soil depth has been confirmed in two beech ecosystem differing in their pollution history. The corresponding values in the Kremnické vrchy Mts, relatively pollution-free, were 6.25 in open area and 6.06 in beech forest stand.

In the Kremnické vrchy Mts, the pH values in throughfall and in lysimetric water were higher than the pH values in free precipitation. In both study localities, the forest stand's influence on the throughfall pH was statistically insignificant.

The pH values can also depend on the total precipitation sum, as abundant rainfall can cause leaching of base elements and shifting pH values towards the acid range.

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