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

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Abstract: Janík R., Schieber B., Bublinec E. 2014: Space-time patterns of soil pH and conductivity in submountain beech ecosystems in the West Carpathians. *Beskydy*, 7 (2): 81–86

The results of pH values monitoring performed for 26 years (1988–2013) in Štiavnické vrchy Mts (middle Slovakia) are summarised. The accumulative trend of acidifying components of forest soils downwards the soil depth has been confirmed. The pH values of soil, exposed to a severe airborne pollution load in the past, were in general lower: from 5.42 in the surface humus decreasing to 4.93 at a soil depth of 0.25 m. On the other hand, the pH values of throughfall and precipitation in open area were comparable. The lower pH values were found in lysimetric water within the forest stand plot at 0.10 m depth (4.50 in 2009). The absolute highest pH were found in the forest throughfall and reached the values of 6.40 in year 1999. The annual dynamics exhibited the highest pH values in the winter and spring. On the other hand, the lowest values were recorded in summer period.

Keywords: pH, acidification, Štiavnické vrchy Mts, beech ecosystem

Introduction

The principal and easiest at hand indicator of soil acidity is their pH and conductivity. Acidification of forest soils belongs to the main factors responsible for significant changes to forest ecosystem diversity in a long term prospect (Bobbink *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, Hruška *et al.* 2001), drop in pH values and lowering the humus quality (Oulehle, Hruška 2005, Borůvka *et al.* 2005, Bonneau 2005).

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. The soil properties display more space variation in O horizons than in B horizons, with

the latter more influenced by soil-forming processes (Svedrup *et al.* 1992).

Despite the 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 soil data submitted by 23 European countries demonstrate acid A horizon in 42% out of the 4532 localities surveyed. In 1.9% cases, the acidity was found even strong (with pH soil reaction under 3). It has been revealed that the higher A-horizon acidity was more frequent in areas with higher acidifying load, in soils with extremely weak buffering capacity against acidification, especially in Holland, Finland and Belgium. On the other hand, the highest resistance against acidification was observed in Luxembourg, Slovakia, Hungary, Slovenia, Portugal, Switzerland and Austria (Anonymous 1999). The forest soil monitoring performed by the Forest Research Centre in Zvolen resulted

in finding out that about one half of the forest plots inspected (from the total of 5843) was, in terms of their soil reaction and base saturation, in the buffer zone aluminium and the soils on almost 10% of them were identified as extremely acid (Kanianska 2007).

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 Štiavnické vrchy Mts (the West Carpathians Mts.). This site, along with site in Kremnické vrchy Mts. will serve as model localities to investigate the impact of airborne pollution load.

Methods

The Study Area

The Štiavnické vrchy Mts. are volcanic mountain massifs belonging to the Slovenské Stredohorie Mts. Intensive agriculture, industry and landscape urbanisation are its typical feature. The set of study plots (stands plot and open plot) is located in NW part of the Štiavnické vrchy Mts., middle Slovakia (48°35'N; 18°51'E). Forest stands are formed by beech (*Fagus sylvatica* L.) of the age 110 years with the original stocking of 0.9. The elevation is 470m a.s.l., slope reaches 20°. The area of the study plots belongs to the moderately warm district with mean annual precipitation of 750mm (min. 431mm, max. 1,020mm). The average air temperature ranges from 8.0 to 8.5 °C, while during the growing period the average air temperature is 14.5–15.5 °C (Kellerová 2005). Geological substrate are rhyolite tuffs and soil type is luvic cambisol.

The Štiavnické vrchy Mts. were strong affected by pollutants from the regional sources (production of aluminium, power industry, transport, waste dump). The main contaminants were oxides of fluorine, sulphur and nitrogen, heavy metals as arsenic and cadmium, ozone and particulate matter. The long-time increased input of these pollutants from air to the ecosystems of the Štiavnické vrchy Mts. caused the changes in the ecological

conditions. This situation led to the negative quality of the beech stands in the study region. The worst effect for the beech forests had sulphur dioxide (SO₂) and fluorine. The region of the Žiarska kotlina basin was regarded for many years as an area with the most polluted environment in Slovakia. For this reason in the 1990's this area was classified to the II.–III. degree of exhalation. Since the end of the 1990's the amount of the pollutants has been decreasing rapidly because of the modernization production processes and more strictly legislation. The concentration of fluorine was cutting down on the tolerable level 1 µg.m⁻³ (Urminská *et al.* 2000).

The lysimetric water was sampled into plastic collectors (1000cm²) in three different soil horizons. The first set is installed in the layer H₀₀, i.e. the surface horizon (organic layer), the second at a depth of 0.10m below the soil surface (upper mineral layer) and the third at 0.25m below the surface (lower mineral layer) (Kukla 2002).

Atmospheric precipitation and through-fall water were collected into funnels issuing in closed collectors (660 cm²). The collectors were spaced regularly throughout the stands and the adjacent open plots (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 and after each relevant precipitation episode (Lindberg, Turner 1988).

The pH values was measured potentiometrically using a WTW INOLAB 720 pH meter (Weilheim, Germany).

The data were processed using the statistical program Statistica 7. Student's t-test for dependent variables was used to assess the statistical significance of differences between the soil horizons.

Results and Discussion

The mean pH value in the surface humus layer was 5.42, with the maximum of 6.06 recorded in 2001, and minimum of 4.82 recorded in 1982. These values indicate an almost strong acid environment. The variation range was only 1.24, and also the variability reached 7.01%. was relative low (Tab. 1).

The Fig. 1 shows a distinct increasing trend in pH values, demonstrating improving conditions for the locality inspected. This fact has also been confirmed by the low values of standard deviation and standard error

Tab. 1: Descriptive statistics of pH in the Štiavnické vrchy Mts (Western Carpathians Mts.) in years 1988–2013.

Lysi meter	F00	F10	F25	Open plot wet deposition	Forest through fall
pH					
Mean	5.42	5.14	4.93	5.86	5.80
Minimum	4.82	4.50	4.58	4.85	4.76
Maximum	6.06	5.57	5.35	6.37	6.40
Range	1.24	1.08	0.77	1.51	1.64
Coefficient of variation	7.01	23.93	3.65	6.45	7.24
Standard Deviation	0.38	1.23	0.18	0.38	0.42
Standard Error	0.07	0.05	0.03	0.08	0.09

F₀₀-F₂₅ Lysimeter in the Forest

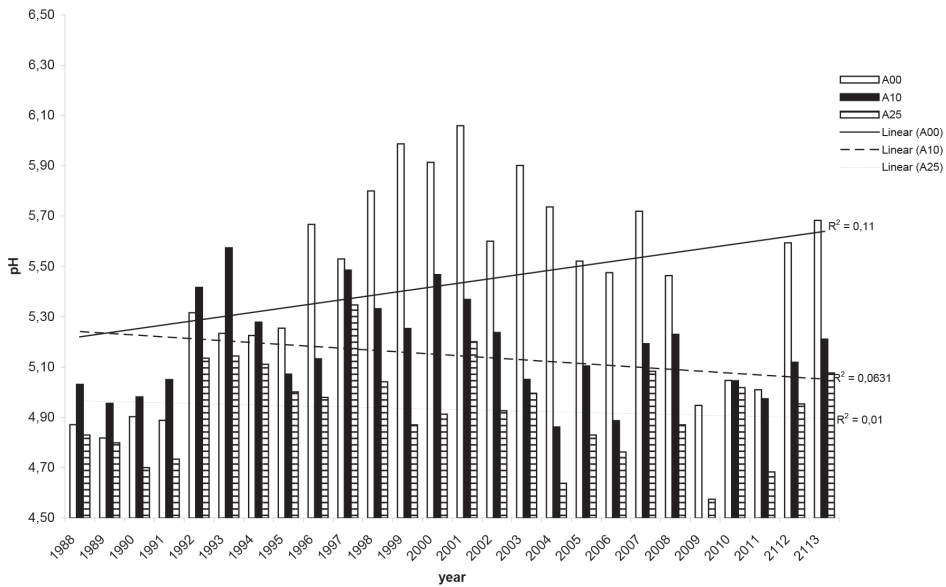


Fig. 1: pH values of soil horizons in the Štiavnické vrchy Mts in the years 1988–2013.

The situation at the depth of 0.1m below the surface was a little different. The mean pH value was lower (5.14), and the strong acidity was also implied by minimum values (4.50) recorded just in 2009. The maximum, representing 5.57 was recorded in 1993. The trend testifies to a moderate decrease in pH values. The variability was almost 24%. (Tab. 1).

The depth of 0.25m manifested the lowest mean pH value (4.93), with the minimum of 4.58 recorded in 2009, and a maximum of 5.37 recorded in 1997. The trend line demonstrated

an increasing tendency. For this depth, all statistical characteristics had the lowest values (Tab. 1). Slight influence of stand composition and canopy structure was also discernible on pH values of the throughfall.

The pH patterns of the precipitation on the open plot and the throughfall were very similar (Tab. 1, Fig. 2).

Somewhat higher mean values were recorded on the open plot (5.86 compared to 5.80 in the stand). In both cases, the trend lines are decreasing. Mindáš (2005) observed the following

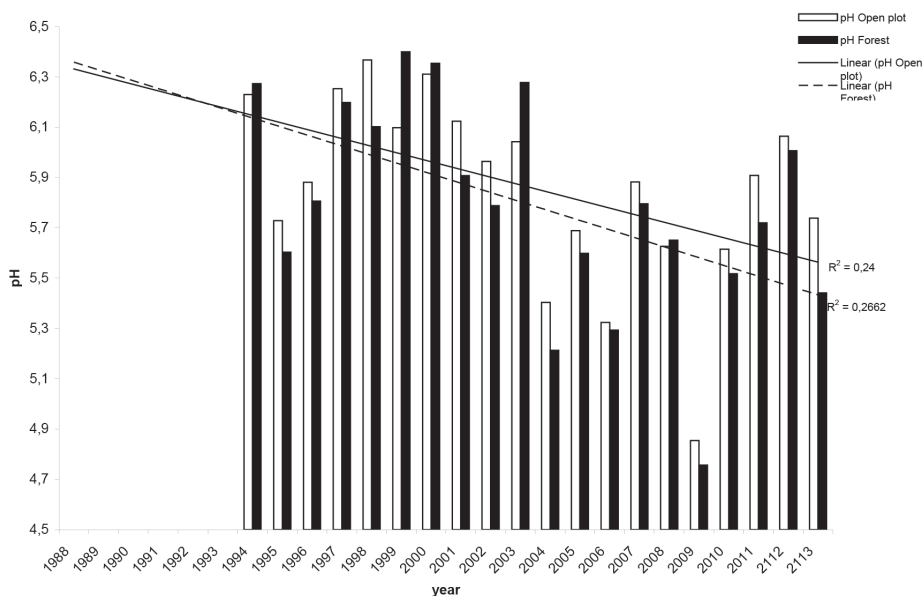


Fig. 2: pH values at the open plot wet deposition and in the forest throughfall in the Štiavnické vrchy Mts in the years 1988–2013.

changes in pH values in the throughfall, compared to the vertical precipitation above the stands: moderate, statistically insignificant ($\alpha = 0.1$) increase after falling through a canopy gap, a negligible change after falling through beech crowns and a statistically significant ($\alpha = 0.01$) shift to more acidity after falling through spruce canopy.

Mihálik *et al.* (1993) studying the chemistry of stemflow (precipitation water flown to the ground along tree stems) in the locality Mláčik in the Kremnické vrchy Mts. (850 m a.s.l.) report the following annual mean values of the active reaction for beech stemflow: 4.47 in 1986, 4.40 in 1987, and 4.96 and 4.72 in 1990 for 130 year-old trees and 15 year-old trees, respectively. The pH value observed in the same year on an open plot was 4.92. A more distinct difference in pH values between the original precipitation and stemflow on 15-year-old beech trees has been reported by Gower *et al.* (1995) from south England (1984–1985): 5.2 on an open plot and 3.3 in the stemflow. This decrease could be due to a higher portion of acid anions of marine origin as well as due to the very small share of beech stemflow representing only less than 1% of the precipitation fallen on the open ground.

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 (Skrzypek *et al.* 2008).

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, where the mean pH value at 0.25 m was 4.25. The corresponding values in the Kremnické vrchy Mts, relatively pollution-free, were 6.25 in open area and 6.06 in beech forest stand.

The pH values in throughfall and in lysimetric water were lower than the pH values in free precipitation. The opposite was true in the Kremnické vrchy Mts.

In both study localities, the forest stand's influence on the throughfall pH was statistically insignificant.

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