Altitude and Forest Type Effects on Soils in the Jizera Mountains Region

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Abstract: This paper is focused on the Jizera Mountains as a region strongly influenced by man in the past. The structure of the natural forest was changed. Species monocultures with similar tree ages were planted. High acidificants concentrations in atmosphere led to the decline of these monoculture forests in the top parts of the mountains and the high acidificants deposition damaged the soils in the whole region. The goals of this study are to describe the distribution of the soil properties in altitude transects, where temperature, precipitation, and vegetation gradients are recorded, and to compare the soil properties in spruce and beech forests. The soil samples were collected from soil pits in a surviving nature-close beech forest, in a production spruce forest, and also in the top dead forest area with a grass cover. Soil samples from sufficiently deep diagnostic horizons were taken for the study of chemical properties. The basic soil characteristics were determined by the commonly used methods (pH, effective cation exchange capacity – eCEC, and the contents of cations in the sorption complex, A_{400}/A_{600} as humus quality parameter, the contents of available Ca, Mg, K and P, pseudototal content of Ca and Mg, and two differently extracted Fe and Al forms contents). The soils of the Jizera Mts. are strongly acid with a low eCEC which is the result of the natural and anthropogenic acidification processes. Soil chemical properties of the most affected top mountainous parts are in some aspects more favourable than lower parts (binding of potentially toxic Al in organic matter, slightly higher pH), but in other aspects they are still endangered by the acidification symptoms (higher leaching of base cations, especially Mg). The soils of nature-close beech forests represent more favourable soil properties than those of planted spruce forests. Generally, it can be concluded that the natural systems have higher resilience, and that natural mechanisms are able to mitigate slightly the soil degradation.

Keywords: forest soils; altitude; forest type; beech; spruce; elevation transects

Soil acidification in the Czech Republic presents a serious problem in forest soils of mountainous areas. Soil acidification is a natural process conditioned by naturally acid parent rocks, high precipitations and slow organic matter decomposition producing various organic acids. This natural system has been disturbed by human activities. Natural stable forest ecosystems were changed to spruce monoculture production forests with acid, hardly decomposed litter. This step led to natural acidification processes acceleration; soil pH decrease and base cation loss increase. A number

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of studies showed the differences in the soil characteristics between broadleaved and coniferous trees, especially between beech (*Fagus sylvatica*) and Norway spruce (*Picea abies*) (for example: Cronan & Grigal 1995; Zimka & Stachurski 1996; Misson *et al.* 2001; Oulehle & Hruška 2005). In 1970's and 1980's, a period of enormous coal mining, thermal power stations and heavy industry development, huge amounts of acidificants (SO_2, NO_X, etc.) were emitted to the atmosphere. High levels of acidificants deposition increase the intensity of soil acidification and change some mechanisms of this process. The presence of mineral non-complexing acids (H_2SO_4, HNO_3) in soils leads to mobilisation of potentially toxic elements like Al or heavy metals (Richter 1986; Hovmand & Bille-Hansen 1999; Pierzynski *et al.* 2000; Hruška & Cienciala 2003). Though sulphur emissions decreased dramatically in the last decades, the effect of S accumulation is long-termed; moreover, the nitrogen deposition is still fairly high (Hruška *et al.* 2001; Hruška & Krám 2003; Uhlířová *et al.* 2002).

This paper deals with the Jizera Mountains region located in the North of Bohemia. The region is one of the areas most affected by human activities in the Czech Republic (Suchara & Sucharová 2002). High concentrations of acidificants in atmosphere, originating mainly from thermal power stations in the Czech Republic and in Poland, also called "Black triangle", occurred in the past. At present, the concentrations of acidificants in atmosphere are decreased. However, the forests still stay threatened by long-term changes of the soil conditions (lower base saturation, lower pH, and high contents of potentially toxic Al forms). In the Jizera Mountains, the damage of soil and forests led to the forest decline in the top parts of the mountains. This area was fast invaded by grass as a natural mechanism of ecosystem restoration. The soils under this grass cover have often better chemical properties than soils covered by forests due to the grass litter quality, its influence on N cycling, organic matter turnover and base cations leaching (Adams & Evans 1989; Kooijman *et al.* 2000; Fiala *et al.* 2001).

This study is a continuation of the project dealing with the whole region of the Jizera Mts. Some results of the complex project showed effects of altitude and forest type on the soil properties distribution (Borůvka *et al.* 2005; Mládková *et al.* 2005, 2006). The goals of this study are to focus on this relationship in greater detail, to describe the distribution of soil properties in altitude transect, and to compare the soil properties in spruce and beech forests.

MATERIAL AND METHODS

Area of interest and sampling

The Jizera Mountains region is plutonic area with uniform granite bedrock. Complex soil studies of this region are presented e.g. in Mládková

Table 1. Description of sampling sites on Paličník and Smědava transects

Pit	Paličník			Smědava		
	soil type	forest	age	soil type	forest	age
1	Haplic Podzol	spruce	40–50	Haplic Podzol	spruce (+ pine)	10
2	Haplic Podzol	beech	80–120	Haplic Podzol	spruce	10
3	Haplic Podzol	spruce	10	Haplic Podzol	spruce	10
4	Haplic Podzol	beech	80	Colluvic Regosol	spruce	10
5	Haplic Podzol	spruce	30–40	Colluvic Regosol	spruce/beech	10/110
6	Haplic Podzol	beech	170	Colluvic Regosol	beech	110
7	Haplic Podzol	spruce	60	Haplic Podzol	beech	150
8	Entic Podzol	beech	80–120	Haplic Podzol	beech (+ birch)	150
9	Entic Podzol	spruce	90	Entic Podzol	beech	140
10	Cambisol	beech	120	Entic Podzol	beech	150

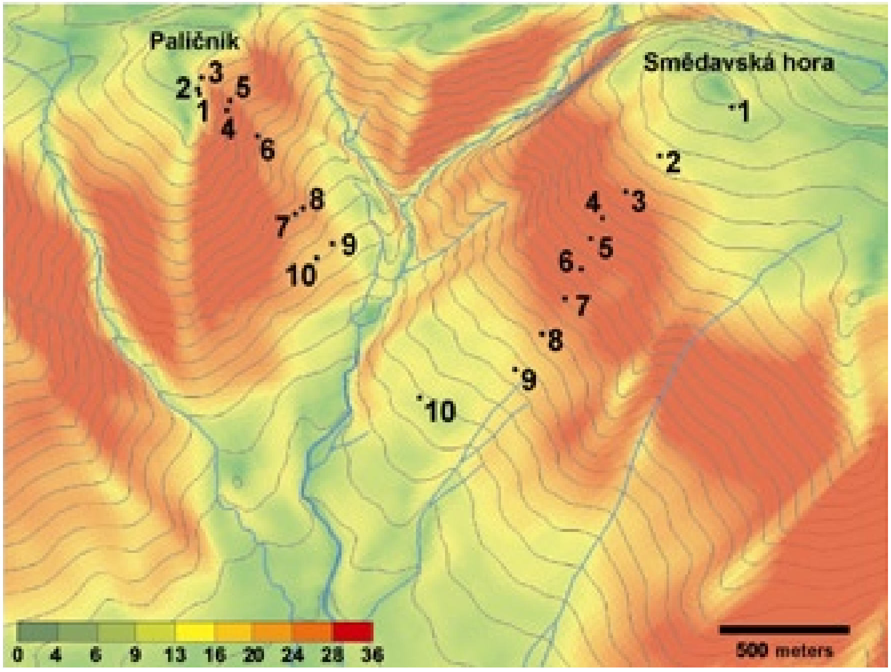

Figure 1. Map of sampling sites with colour emphasise of steepness (degree); scale change with distance, equidistance is 25 m (Paličník – 972 m, Smědavská hora – 1084 m)

et al. (2004, 2005, 2006), Borůvka *et al.* (2005). This paper deals with two elevation transects in the north part of this region (Figure 1, Table 1). The first transect, Paličník, represents the altitude range from 600 m to 950 m with western orientation. The soil samples were collected from ten soil pits. Five soil pits are placed in a different age spruce forest (*Picea abies*) and five in a more than 100 years old nature-close beech forest (*Fagus sylvatica*). The soil type changes with decreasing altitude from Haplic Podzols over Entic Podzols to Cambisols. The second transect, Smědava, represents the altitude range from 600 m to 1050 m with northern orientation. The soil samples were collected also from ten soil pits. The forest cover differs with decreasing altitude from the dead forest with young free-growing spruce and a high grass abundance to old beech forest. Haplic Podzols are the prevailing soil types. The middle steepest part of the slope contained Colluvic Regosols while that of the altitude of around 600 m Entic Podzols.

Basic soil characteristics

The soil samples were collected from sufficiently deep soil horizons: organic fermented (F), organic humified (H), mineral humic (A), mineral albic (eluvial) (E), mineral spodic humic-sesquioxidic, spodic sesquioxidic, spodic red, and cambic (B) soil horizons, and the substrate (C). In total, 104 samples were collected. The samples were air dried in room temperature and sieved through 2 mm mesh.

Basic soil characteristics were determined. The values of pH_{H_2O}, pH_{CaCl_2}, and pH_{KCl} were measured potentiometrically. Humus quality was assessed by the ratio of absorbances of pyrophosphate soil extract at the wavelengths of 400 nm and 600 nm (A_{400}/A_{600} – Pospíšil 1981). Organic carbon content (C_{org}) was determined oxidimetrically by a modified Tjurin method (Pospíšil 1964); this analysis was done only on samples from the mineral horizons. Available nutrient contents were determined in Mehlich III extract (P_{MIII}, K_{MIII}, Ca_{MIII}, Mg_{MIII}) (Zbíral 2002). Pseudo-total contents of Ca and Mg were measured after soil digestion with aqua regia (Ca_{AR}, Mg_{AR}) (Zbíral 2002). Effective cation exchange capacity (eCEC) was determined by the Mehlich method with unbuffered 0.1M $BaCl_2$ extraction solution (Podlešáková *et al.* 1992). The contents of exchangeable elements were measured together with eCEC (Ca_{exc}, Mg_{exc}, K_{exc}, Na_{exc}, Mn_{exc}, Al_{exc}). The contents of two different Al forms were determined according to Drábek *et al.* (2003): potentially toxic Al forms were extracted with 0.5M KCl solution (Al_{KCl}), and organically bound Al forms were extracted with 0.05M $Na_4P_2O_7$ solution ($Al_{Na_4P_2O_7}$). The contents of iron forms were measured in the same extracts as Al (Fe_{KCl}, $Fe_{Na_4P_2O_7}$). Aluminium and iron concentrations in both extracts were determined by means of ICP-OES (inductively coupled plasma – optical emission spectrometry, VARIAN Vista Pro, VARIAN, Australia). Statgraphics Plus for Windows 4.0 (Manugistics 1997) was used to perform correlation analysis and *t*-tests.

RESULTS AND DISCUSSION

Maximum and minimum values of the studied soil properties are shown separately for each transect in Tables 2–5. For a better illustration, Figures 2 and 3 show the distribution of the selected soil characteristics on both transects in the H horizon. This horizon was picked out because of its similarity in all soil pits from the pedogenesis point of view.

Acidity of the surface soil horizons ranges from strong to very strong (Table 2). Deeper horizons are less acid. Humus quality is rather low as it is typical for forest soils (Table 2). Table 3 shows the characteristics of the soil sorption complex. Soil sorption capacity decreases with the depth of the soil horizon, probably due to the decreasing of organic matter content. It is evident that the main part of the sorbed cations is composed of aluminium ions. The ratio of the base cations to Al ions in the soil sorption complex is less than 1. However, the criteria of this ratio evaluation (where commonly used critical value is 1) exist only for the soil solution (Cronan & Grigal 1995). The contents of the available elements decrease with depth (Table 4). While the pool of these elements is almost sufficient in the surface organic horizon, it is very low in the mineral horizons. The contents of P_{MIII} are often below the detection limit, and also Mg_{MIII} contents in the deepest mineral horizons are below this limit. The distribution of Mg_{AR} in the soil profile does not correspond to Mg_{MIII} distribution mentioned above. Pseudototal Mg content increases with depth and this distribution corresponds more to the high leaching in acid conditions. The distribution of Ca_{AR} corresponds probably to the distribution principles of the podzolization process. The lowest contents are found in eluvial E horizon. Al and Fe forms distribution in the soil profile is controlled by the podzolization process (Table 5). Their release from the E horizon and transport to the B horizon is the principal mechanism of this process. The relative assessment of this process intensity and the contents of the released potentially toxic Al forms could be a good indicator of the acidification level.

Table 2. Maximum and minimum values of studied basic soil characteristics on the Paličník and Smědava transects separately for soil horizons

Horizon (samples)	pH_{H_2O}		pH_{KCl}		pH_{CaCl_2}		C_{org} (%)		A_{400}/A_{600}	
	min	max	min	max	min	max	min	max	min	max
Paličník transect										
F (10)	3.57	4.49	2.66	3.28	2.80	3.40			7.22	25.65
H (10)	3.09	4.02	2.83	3.42	2.90	3.50			7.71	17.00
A (5)	3.51	4.06	2.87	3.43	3.10	3.70	5.73	10.52	3.70	7.86
E (4)	3.69	3.87	3.04	3.25	3.25	3.45	4.01	7.86	4.88	6.04
B (19)	3.64	4.54	2.99	4.19	3.25	4.30	3.01	9.55	5.79	11.82
C (7)	4.45	4.63	4.05	4.25	4.10	4.45	0.98	4.48	3.57	12.19
Smědava transect										
F (8)	3.85	4.38	2.89	3.51	3.05	3.65			7.19	19.67
H (10)	3.85	4.15	3.02	3.64	3.15	3.80			6.20	10.50
A (5)	3.76	4.17	3.13	3.57	3.30	3.75	6.73	10.27	4.12	11.32
E (4)	3.95	4.33	3.33	3.61	3.55	3.85	1.67	7.54	4.68	8.42
B (8)	3.96	4.56	3.37	4.27	3.60	4.55	1.15	9.60	4.38	10.47
C (6)	4.44	4.59	3.89	4.35	4.15	4.55	1.10	5.14	3.73	10.53

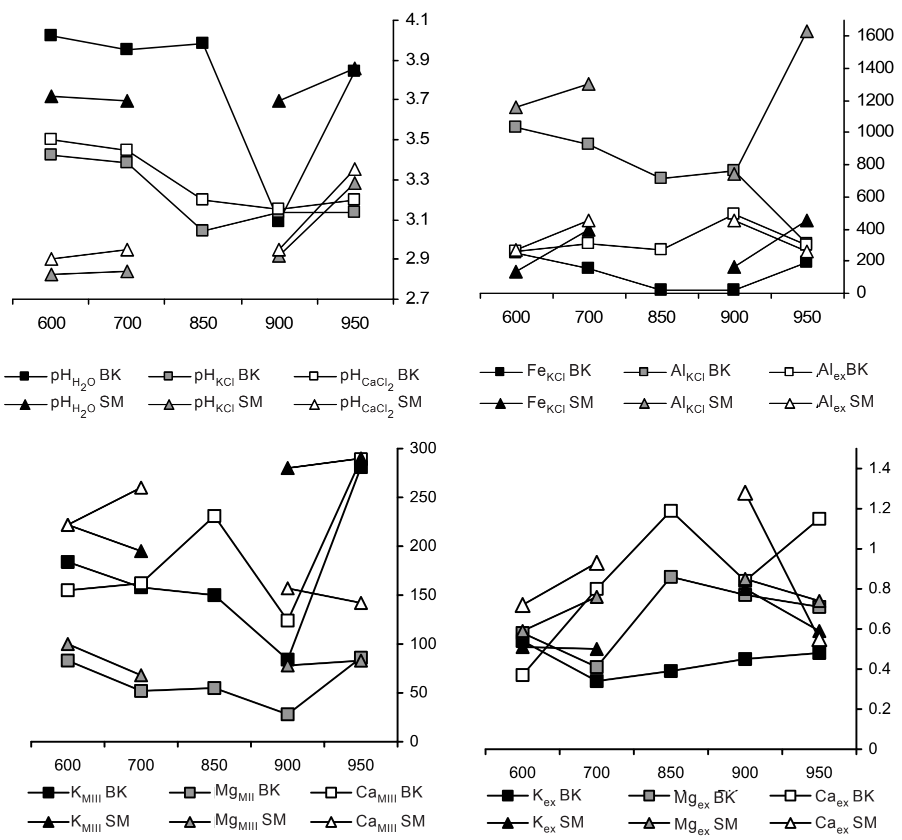

Figure 2. Selected H horizon soil properties distribution on Paličník transect separately for beech (BK) and spruce (SM) forest (exchangeable cations contents (K_{ex}, Mg_{ex} and Ca_{ex}) are presented in mmol/100 g, all other elements contents are presented in mg/kg).

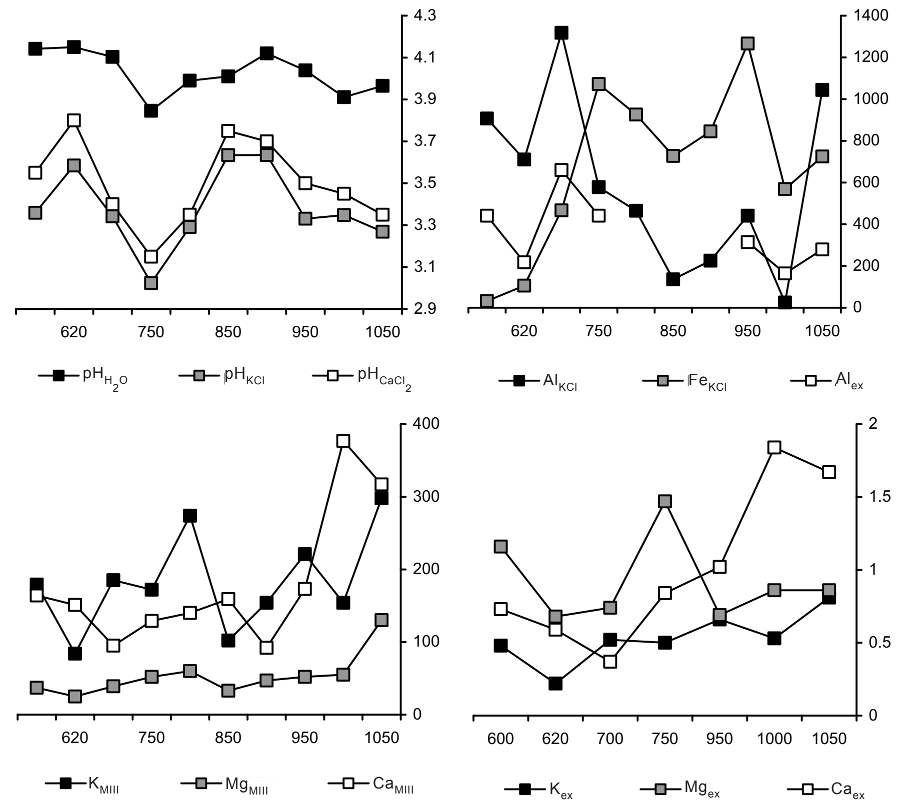

Figure 3. Selected H horizon soil properties distribution on Smědava transect (exchangeable cations contents (K_{ex}, Mg_{ex} and Ca_{ex}) are presented in mmol/100 g, all other elements contents are presented in mg/kg).

Table 3. Maximum and minimum values of soil sorption parameters on the Paličník and Smědava transects separately for soil horizons (eCEC and exchangeable cations contents are presented in mmol/100 g; Al_{ex} detection limit is 0.5 mmol/100 g)

Horizon (samples)	eCEC		Ca_{ex}		Mg_{ex}		K_{ex}		Na_{ex}		Mn_{ex}		Al_{ex}	
	min	max	min	max	min	max	min	max	min	max	min	max	min	max
Paličník transect														
F (7)	20.39	26.05	1.68	7.25	0.70	1.19	0.54	1.37	0.07	0.10	0.03	0.12	9.39	21.35
H (10)	10.13	27.03	0.37	1.28	0.41	0.86	0.34	0.80	0.06	0.09	0.01	0.05	3.76	18.38
A (5)	8.89	12.07	0.20	0.66	0.33	0.53	0.17	0.23	0.05	0.06	0.01	0.08	6.27	8.45
E (4)	7.21	10.45	0.35	0.62	0.15	0.49	0.10	0.22	0.05	0.08	0.01	0.01	4.56	9.20
B (19)	4.13	14.80	0.06	6.60	0.10	0.64	0.05	0.23	0.04	0.11	0.00	0.09	2.98	17.34
C (7)	1.64	4.41	0.09	0.43	0.23	0.53	0.04	0.08	0.03	0.16	0.01	0.03	<0.5	3.16
Smědava transect														
H (7)	10.06	24.00	0.37	1.84	0.68	1.47	0.22	0.81	0.04	0.10	0.01	0.30	6.07	24.44
A (3)	11.10	11.91	0.46	0.69	0.25	0.95	0.15	0.22	0.05	0.06	0.01	0.05	7.20	9.92
E (4)	2.87	9.82	0.28	0.45	0.21	1.25	0.05	0.11	0.04	0.06	0.01	0.03	0.24	8.65
B (8)	1.08	12.92	0.16	0.74	0.15	1.25	0.05	0.26	0.04	0.05	0.00	0.24	1.99	11.87
C (6)	0.88	5.81	0.16	0.48	0.11	0.69	0.05	0.07	0.04	0.05	0.01	0.05	0.80	5.85

Assessment of altitude effect

The altitude effect was assessed by correlation analysis. The results from the Paličník transect are shown in Table 6. The content of Al_{KCl} in the surface organic horizons decreases with increasing altitude in the Paličník transect. It could indicate that a higher portion of Al is bound in organic matter in the higher parts of the transect. Negative correlations of Al_{KCl} contents in A and E horizons could be explained rather by a stronger podzolization process in the higher parts of the transect.

Table 4. Maximum and minimum values of available and pseudototal contents of studied elements on the Paličník and Smědava transects separately for soil horizons (all values are presented in mg/kg; detection limit is 10 mg/kg for available contents)

Horizon (samples)	P_{MIII}		K_{MIII}		Mg_{MIII}		Ca_{MIII}		Mg_{AR}		Ca_{AR}	
	min	max	min	max	min	max	min	max	min	max	min	max
Paličník transect												
F (10)	< 10	58	199	481	70	196	225	1630	524	1444	237	2058
H (10)	< 10	62	84	290	28	100	124	322	321	1871	201	525
A (5)	< 10	28	60	97	20	39	89	188	1136	2289	245	346
E (4)	< 10	<10	33	93	11	25	96	136	647	1567	129	330
B (19)	< 10	22	20	102	<10	58	38	147	1258	4031	167	544
C (7)	< 10	26	18	37	<10	50	55	123	3092	6303	441	1102
Smědava transect												
F (8)	< 10	25	164	677	47	186	129	906	809	1857	353	1380
H (10)	< 10	13	84	298	25	130	92	377	515	2318	255	615
A (5)	< 10	<10	46	82	19	29	72	153	904	3915	319	517
E (4)	< 10	<10	16	37	12	23	77	242	418	1450	248	316
B (8)	< 10	<10	16	94	<10	25	45	152	1516	4248	268	477
C (6)	< 10	23	19	28	<10	15	52	109	1246	5462	289	642

Table 5. Maximum and minimum values of studied Al and Fe forms contents on the Paličník and Smědava transects separately for soil horizons (all values are presented in mg/kg)

Horizon (samples)	Al_{KCl}		$Al_{Na_4P_2O_7}$		Fe_{KCl}		$Fe_{Na_4P_2O_7}$	
	min	max	min	max	min	max	min	max
Paličník transect								
F (10)	212.2	1 710.0	1 057.3	9 216.9	18.1	679.2	1 466.3	5 388.8
H (10)	310.2	1 633.4	1 885.8	13 229.7	18.3	453.7	2 498.4	8 132.3
A (5)	351.6	969.7	1 094.7	5 656.9	91.1	258.7	1 613.2	7 445.7
E (4)	307.6	737.4	1 074.7	1 677.8	62.2	173.0	347.0	3 559.1
B (19)	230.7	1 089.7	2 033.5	12 723.5	9.6	595.6	1 862.7	19 627.5
C (7)	140.5	281.3	2 188.5	7 006.7	8.2	19.6	300.6	3 825.4
Smědava transect								
F (8)	220.1	929.2	1 602.9	7 707.1	158.4	1 075.2	2 401.8	6 872.6
H (10)	24.8	1 318.1	3 344.4	8 565.0	31.8	1 266.6	4 764.9	8 490.6
A (5)	83.0	999.7	1 608.9	6 263.9	250.8	759.0	4 009.3	7 260.6
E (4)	69.1	887.7	100.2	1 646.6	43.5	417.8	183.6	1 553.2
B (8)	10.6	1 304.4	3 143.1	10 582.8	8.1	434.4	341.8	11 427.2
C (6)	9.4	486.4	1 654.9	7 350.0	6.0	371.8	132.8	5 034.1

The same process could explain the positive correlation of $Fe_{Na_4P_2O_7}$ content with altitude in the B horizons. The results also showed negative correlation between Mg_{AR} and altitude in the surface organic and mineral A and E horizons. Higher precipitation amounts in higher altitude and the consequent higher leaching could be responsible for this fact. However, no correlation was found in the case of Mg_{MIII}, where sorption on organic matter could play an opposite role.

The results of correlation analysis for the Smědava transect are shown in Table 6. Mg_{AR} content in the surface horizons decreases with increasing altitude in the Smědava transect as well as in the Paličník transect. The B horizons are also enriched with $Fe_{Na_4P_2O_7}$ and, moreover, with $Al_{Na_4P_2O_7}$ in the Smědava transect. Al_{KCl} content decreasing with increasing altitude was not found in the surface horizons of this transect, but it was found in the A and E horizons.

The situation that correlation is in many cases rather weak can be caused in part by the fact that the relationship does not need necessarily to be linear. The search for a non-linear function describing the relationship between altitude and soil properties will be underway in further research.

Generally, we can say that altitude has no effect by itself. Different altitudes represent changes in temperature, precipitation amount, vegetation cover, deposition rate, and so on. Soil chemical properties of the most affected top mountainous parts are in some aspects more favourable than those of lower parts (binding of potentially toxic Al in organic matter, slightly higher pH). Natural mechanisms as grass expansion in dead forests are able to mitigate slightly the soil degradation. In other aspects, this mountainous parts are still endangered by acidification symptoms (higher leaching of base cations, especially Mg).

Assessment of forest type effect

The Paličník transect to altitude 900 m was used for the assessment of the forest type effect on soil chemical properties. The soil pits placed above 900 m appertain to different vegetation zones by forest typology and for this reason they were removed from the data set evaluated. The results of the *t*-test performed are shown in Table 7. Beech

Table 6. Correlation coefficients of relationships of altitude versus studied soil properties on the Paličník and Smědava transects separately for soil horizons or groups of soil horizons; significant correlations at the significance level of 0.05 are in bold letters

Characteristic	All horizons	F + H	F	H	A+E	B	C
Paličník transect							
pH_{H_2O}	–0.048	0.111	0.386	–0.193	–0.002	–0.123	0.535
pH_{KCl}	–0.111	–0.030	0.031	–0.090	–0.009	–0.216	0.395
pH_{CaCl_2}	–0.128	–0.019	0.057	–0.095	–0.152	–0.267	–0.214
C_{org}	0.267				–0.186	0.240	0.345
A_{400}/A_{600}	–0.166	–0.173	–0.213	–0.147	–0.530	–0.062	–0.163
Al_{KCl}	–0.263	**–0.509**	–0.610	–0.396	**–0.675**	0.019	–0.237
$Al_{Na_4P_2O_7}$	0.171	0.201	0.080	0.301	–0.062	0.171	**0.907**
Fe_{KCl}	–0.228	–0.367	–0.565	–0.133	–0.253	–0.252	0.632
$Fe_{Na_4P_2O_7}$	0.217	–0.217	–0.550	–0.083	–0.203	**0.548**	0.619
P_{MIII}	0.226	0.342	0.555	0.212	0.596		
$K_{M\ III}$	0.059	0.210	0.240	0.320	0.031	**0.513**	0.314
Mg_{MIII}	–0.133	0.091	0.301	–0.251	–0.371	**–0.824**	–0.439
Ca_{MIII}	0.119	0.254	0.377	0.169	0.307	0.242	–0.315
Mg_{AR}	**–0.286**	**–0.606**	–0.562	**–0.672**	**–0.687**	–0.361	–0.359
Ca_{AR}	0.021	0.238	0.360	0.129	–0.230	–0.196	0.091
eCEC	–0.054	–0.049	–0.264	0.166	**–0.717**	0.318	–0.112
Ca_{exc}	0.131	0.206	0.598	0.573	0.458	0.231	0.482
Mg_{exc}	–0.050	0.059	0.155	0.339	–0.247	0.364	–0.441
K_{exc}	–0.081	–0.035	0.164	0.156	–0.067	0.445	0.093
Na_{exc}	**0.283**	0.117	0.408	0.274	0.197	**0.552**	0.480
Mn_{exc}	–0.107	–0.272	–0.184	–0.181	0.126	0.162	–0.021
Al_{exc}	0.114	0.016	0.275	–0.041	–0.155	0.398	0.518
Smědava transect							
pH_{H_2O}	–0.145	–0.177	0.053	–0.504	0.239	–0.281	0.083
pH_{KCl}	–0.177	0.105	0.469	–0.056	0.344	–0.459	–0.704
pH_{CaCl_2}	–0.227	–0.020	0.317	–0.180	–0.004	–0.504	–0.579
C_{org}	–0.040				–0.276	0.198	0.252
A_{400}/A_{600}	0.023	0.355	**0.748**	–0.406	–0.383	–0.625	0.007
Al_{KCl}	–0.231	–0.196	0.292	–0.409	**–0.795**	0.268	–0.692
$Al_{Na_4P_2O_7}$	0.177	0.389	0.532	0.413	–0.016	**0.713**	0.234
Fe_{KCl}	**0.385**	**0.475**	0.282	0.602	–0.021	0.589	0.833
$Fe_{Na_4P_2O_7}$	0.135	0.365	0.620	0.331	–0.196	**0.835**	0.020
P_{MIII}	–0.115	–0.379	**–0.881**				
$K_{M\ III}$	0.142	0.204	0.114	0.432	–0.138	0.212	0.150
Mg_{MIII}	0.181	0.315	0.087	**0.676**	0.437	0.154	–0.182
Ca_{MIII}	0.141	0.047	–0.268	0.630	0.508	**0.734**	**0.828**
Mg_{AR}	**–0.449**	**–0.706**	–0.532	**–0.820**	–0.514	0.001	–0.667
Ca_{AR}	0.068	–0.017	–0.340	0.623	0.165	0.508	–0.310
eCEC	0.256	0.386		0.252	–0.637	0.629	0.507
Ca_{exc}	**0.418**	0.610		**0.870**	0.094	**0.867**	0.581
Mg_{exc}	–0.244	0.042		–0.233	–0.544	–0.603	–0.299
K_{exc}	0.330	0.617		**0.781**	–0.184	0.128	0.716
Na_{exc}	**0.454**	**0.904**		**0.889**	–0.342	0.173	0.553
Mn_{exc}	–0.063	–0.469		–0.474	–0.398	0.465	0.200
Al_{exc}	–0.133	–0.492		–0.482	**–0.839**	0.402	–0.112

Table 7. *t*-values of the difference between beech and spruce forests on the Paličník transect; plus values present higher levels of concrete characteristic in beech forest, minus values in spruce forest; significant differences at the significance level of 0.05 are in bold letters

Characteristic	F	H	Bhs	C
pH_{H_2O}	1.272	0.155	1.116	0.499
pH_{KCl}	**4.141**	**2.979**	3.505	–1.543
pH_{CaCl_2}	**6.306**	**3.017**	4.243	
C_{org}			–1.293	**–6.934**
A_{400}/A_{600}	–1.470	0.648	1.134	–3.092
Al_{KCl}	–2.080	**–3.102**	–2.820	4.108
$Al_{Na_4P_2O_7}$	0.940	1.145	1.673	–2.026
Fe_{KCl}	**–3.243**	–1.284	**–8.222**	–1.382
$Fe_{Na_4P_2O_7}$	–0.140	–0.190	–0.170	–0.737
P_{MIII}	0.017	–1.327		
K_{MIII}	0.255	–1.956	1.223	–0.680
Mg_{MIII}	0.255	–1.511	–2.280	–1.482
Ca_{MIII}	–1.749	–2.040	–0.057	–0.693
Mg_{AR}	1.010	0.434	0.389	–0.478
Ca_{AR}	1.202	1.180	–0.005	–1.213
eCEC	**–3.088**	–0.834	0.384	0.706
Ca_{exc}	–0.092	–0.096	**4.561**	
Mg_{exc}	0.478	–0.126	–2.600	–0.728
K_{exc}	0.588	–1.161	1.400	–0.200
Mn_{exc}	0.000	–0.195		0.447
Al_{exc}	–0.670	–0.251	1.165	–0.292

forest soils had significantly higher pH (except pH_{H_2O}) in the surface organic horizons than spruce forest soils. Also, they contained less Al_{KCl} and Fe_{KCl} and they had lower eCEC in these horizons than spruce forest soils. This may be in connection with the lower content of organic matter in beech forest caused by an easier decomposition of leaves. Beech forest soils contained more Ca_{AR} and Mg_{AR} in the surface organic horizons, but this result was not significant.

The higher C_{org} content in the C horizon of spruce forest soil could indicate an easier migration of the low quality organic matter through the soil profile to deeper soil horizons. The soils of natural close beech forests represent more favourable soil properties than the soils of planted spruce forests on the same stand.

Generally, it can be concluded that natural systems presented by beech forest have higher resilience to anthropogenic changes.

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