Study of Podzolization Process under Different Vegetation Cover in the Jizerské hory Mts. Region

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Abstract

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The development of Podzols is conditioned by many factors. One of them is vegetation cover. The aim of this study was to examine in detail special chemical properties, micromorphological features and water retention ability of Podzols under two different vegetation covers (spruce forest and grass). The study was performed in the Jizerské hory Mts., which were strongly influenced by atmospheric acidificant depositions in the past. The study was focused on the assessment of a 30-year grass amelioration impact on soils on the former forest land. It was shown that larger differences in the studied chemical properties (pH_{KCl}, pH_{H_2O}, eCEC, content of Ca, Mg, Al_{KCl}, Al_{H_2O}, $Al(X)^{1+}$, $Al(Y)^{2+}$ and Al^{3+} species) were in the surface organic horizons and decreased with depth. Podzolization intensity was higher under the spruce forest than under the grass cover. Higher amounts of potentially dangerous Al forms were detected in the soils under the spruce forest than under the grass. Grass expansion on clear-cut areas (former forest) as a natural amelioration step results in the particular restoration of soil conditions. The micromorphological features studied on the soil thin sections using the optical microscope and soil water retention curves measured on the undisturbed 100 cm^3 soil samples showed a significant influence of the organic matter presence on the soil structure and retention ability of H and Bhs horizons. Soil under the grass cover had denser structure (e.g. greater fraction of small capillary pores) and higher retention ability than soil under the spruce forest. Very similar retention curves were measured in the Ep and Bs horizons under both vegetation covers. Micromorphological features studied on the thin soil sections clearly documented a podzolization mechanism (e.g. organic material transport and its accumulation, weathering process and Fe oxidation and mobilization).

Keywords: grass; micromorphological features; podzolization process; soil water retention; spruce forest

Podzols are defined as soils with a typically ash-grey upper subsurface horizon, bleached by a loss of organic matter and iron oxides, on top of a dark accumulation horizon with brown, reddish or black illuviated humus and/or reddish Fe compounds. They occur mainly in humid areas in the boreal and temperate zones especially in level to hilly land under heather and/or coniferous forest. The low nutrient status, low level of available moisture and low pH make Podzols unattractive soils for arable farming. Aluminium toxicity and P deficiency are common problems (IUSS Working Group WRB

2006; Yanai 1988). Podzolization is a typical pedogenetic process mostly taking place on acid and silicate rocks, and sand deposits (Lundström *et al.* 2000). Podzolization features however may occur even in mafic and ultramafic materials as it was documented by D'Amico *et al.* (2008).

A podzolization process was described in detail by Sauer *et al.* (2007). Two major groups of processes have been proposed to explain Podzol formation (podzolization): (a) creation and downward transport of complexes of organic acids with Al and Fe; and (b) silicate weathering followed by downward transport of Al and Si as inorganic colloidal sol (Lundsröm *et al.* 2000). The portion of "organic" or "inorganic" complexes in transport process and their formation, precipitation, adsorption or degradation were the object of numerous studies (Lundström *et al.* 2000; Farmer & Lumsdon 2001; Fritsch *et al.* 2009, 2011; Sanborn *et al.* 2011).

The organic matter content, its quality and mobilization play an important role in weathering of minerals and transfer of metal ions (Fritsch *et al.* 2009, 2011). The organic matter chemical structure may vary not only within the soil profile but also within the area depending on the horizontal water fluxes (Fritsch *et al.* 2009; Bardy *et al.* 2011). The impact of climate on soil organic matter properties was documented by Pereverzev (2011). It was shown that while no difference between the particle-size and total chemical compositions of Podzols in the region of the Kola Peninsula was found, humus content in the mineral profile and organic matter enrichment with nitrogen increased with climatic severity.

Podzolization is a long-term process (Alexandrovskiy 2007). The formation of well differenced soil profile represents approximately 300–3000 years depending on climate conditions. However, chemical changes conditioned for example by vegetation cover change or by acid rains are faster. There are numerous examples of increasing or decreasing podzolization intensity by planting respectively changing coniferous forest (Lundström *et al.* 2000; Dlouhá *et al.* 2009). The influence of vegetation cover on soil properties is the object of several projects of our team and also of this paper. Generally, it is possible to say that more favourable conditions are represented by soils (in this case Podzols and also Cambisols) under beech (*Fagus sylvatica*) than spruce (*Picea abies*) forest (Mládková *et al.* 2005, 2006; Borůvka *et al.* 2005a; Pavlů *et al.* 2007). A positive effect of grass cover that replaced damaged spruce forest on soil chemical properties was also reported (Kooijman *et al.* 2000; Fiala *et al.* 2001; Borůvka *et al.* 2005a, b, 2007; Drábek *et al.* 2007). The most of differences was found in surface organic soil horizons. Chemical properties of deeper mineral horizons are similar under beech forest, spruce forest or under grass cover. Development of Podzols in a very short time was documented by Stützer (1998) and Caner *et al.* (2010).

The various forest covers have a great impact on the water regime and transport of dissolved substances in the soil profile and consequently on the soil degradation processes. Studies are usually aimed at the physical and hydraulic properties of mineral soil horizons under the organic matter horizons (Berger & Hager 2000; Heiskanen & Häkitalo 2002). Ellerbrock *et al.* (2005) studied the impact of the composition of organic matter fractions on wettability of three forest soils. Different micromorphology of surface organic horizon H and its hydraulic properties in soils with spruce forest and grass cover were described by Kodešová *et al.* (2007). Substances transport (e.g. podzolization process) may be enhanced due to the redistribution of rainfall in forests (e.g. stemflow and throughfall). The increased Al leakage from the Haplic Podzol close to the tree stem in a beech forest was modelled by Nikodem *et al.* (2010) using the HYDRUS-1D and HYDRUS-2D programs. Leaching of Al and SO_4^{2-} under beech, spruce and grass cover was also studied by Nikodem *et al.* (2013). This study showed a greater impact of beech trees on Al and SO_4^{2-} leakage in comparison with that influenced by spruce trees.

As it was documented, there are studies which deal with selected soil properties of Podzols. However, there is no study that would combine the evaluation of chemical, micromorphologial and hydraulic properties to assess the impact of different vegetation cover on soil properties of Podzols. Therefore the aim of this study was to examine in detail specific chemical properties, micromorphological features and water retention ability of Podzols under two different vegetation covers (spruce forest and grass). The study was focused on the assessment of a 30-year grass amelioration impact on soils on the former forest land. Another goal of this study was to document features characterizing the intensity of an early stage of podzolization process in the areas impacted by human activities in the past.

MATERIAL AND METHODS

Studied region. Mountainous areas in the north of the Czech Republic, the Jizerské hory Mts., were selected to study forest soils in environments influenced by man. The Jizerské hory Mts. region is strongly affected by human activities and belongs among the most damaged areas in the Czech Republic (Suchara & Sucharová 2002). High concentrations of acidificants in the atmosphere, generated mainly by thermal power stations in the Czech Republic and in Poland, occurred in the past. Emissions of SO_2 peaked in the 1980s at 800 000 t/year and decreased to 50 000 t in 2003 (CHMI 2012). At present, concentrations of acidificants in the atmosphere have decreased; nevertheless, high amounts of S and N are accumulated in soils (Hruška *et al.* 2001a; Uhlířová *et al.* 2002) and forest health has not improved significantly (Hruška *et al.* 2001b).

The altitude of the areas ranges from approximately 500 to 1100 m a.s.l. Average annual temperatures are in the range from 3 to 6°C with respect to altitude. The annual precipitation amount is 1500 mm. The acid bedrock of the areas is built of granite and gneiss. Podzols and Cambisols are prevailing soil units in the area. Mor is a prevailing humus form. Only at lower altitudes, moder humus form was found. Natural forest cover of the mountains consists of beech (*Fagus sylvatica*) or mixed beech-spruce (*Picea abies*) forests. In the past, these natural forests were largely converted to spruce monocultures. The highest parts of the mountains are covered by reed grass (*Calamagrostis villosa*) to a large extent because of acid rain damage to the spruce forest, but new young trees, mainly spruce (*Picea abies* or *Picea pungens*), have been planted there recently.

Description of sites and soil properties. The study was performed in the Jizerské hory Mts. in 2005. Three localities were selected: Jizerka (JIZ), Kristiánov (KR), and Protržená přehrada (PR). The altitudes of these localities were around 900, 780, and 840 m a.s.l., respectively. Two variants with different vegetation cover were selected in each locality. The first variant represents soils of clear-cut areas with grass cover composed mainly of *C. villosa*. The second variant represents soils formed in the surviving Norway spruce forest with no understory. Variants in each locality were selected in a geographically restricted zone so that initial conditions were similar. It must be mentioned that deforestation and subsequent grass expansion (the grass variant) took place approximately 30 years prior to sampling (e.g. the soil at both locations was assumed to have similar soil properties 30 years ago). Three soil profiles of each variant and in each area were sampled. Soil was classified as Haplic Podzol on each site (IUSS Working Group WRB 2006). The parent material consisted of granites. Samples were collected when the soil horizon thicknesses were sufficient, in most cases the surface organic horizons (F – fermentation horizons, H – humified horizons), organomineral humic horizons (A), eluvial albic horizons (Ep), spodic humus-sesquioxidic (Bhs) and sesquioxidic (Bs) horizons, and substrate horizons (C) (Table 1).

Table 1. Thicknesses of soil layers

Locality	Horizon	Forest	Grass
		thickness (cm)	
JIZ	L	3	3
	F	3	6
	H	12	7
	Ae	1	1
	Ep	9	10
	Bhs	14	3
	Bs	11	18
KR	L	2	2
	F	1.5	1
	H	4	9
	Ep	1	5
	Bhs	5	9
	Bs	42.5	6
PR	L	1	8
	F	3	3
	H	5	6
	Ae	0	10
	Ep	1	10
	Bhs	7	3
	Bs	12	6

JIZ – Jizerka; KR – Kristiánov; PR – Protržená přehrada; L – slightly decomposed organic material, leaves or needles; F – more decomposed material; H – totally decomposed organic material with potential mineral addition (Green *et al.* 1993); Ep – eluvial albic horizons; Bhs – spodic humus-sesquioxidic; Bs – sesquioxidic horizons

Chemical properties. Samples were air dried and passed through 2 mm sieves. Basic soil characteristics were determined by methods described below. Active and exchangeable soil reaction (pH_{H_2O} and pH_{KCl}, respectively) were determined potentiometrically. Total contents of C, N and S were measured by LECO CNS-2000 automated analyser (LECO Corporation, St. Joseph, USA). Effective cation exchange capacity (eCEC) of mineral horizons was determined by the Mehlich method with unbuffered 0.1M $BaCl_2$ extraction solution (Podlešáková *et al.* 1992). Pseudototal contents of Ca and Mg were measured after soil digestion with aqua regia. Contents of exchangeable Al forms were extracted with 0.5M KCl (Al_{KCl}) (Drábek *et al.* 2003). Aluminium concentration in the extract was determined by means of ICP-OES (inductively coupled plasma – optical emission spectrometry, VARIAN Vista Pro, VARIAN, Mulgrave, Australia).

Air dried soil samples were extracted with deionized water for Al speciation under laboratory temperature (approx. 22°C). W/V ratio was 1:10 and extracting time was 24 h. Extracts were separated from the suspension by centrifugation and further purified by passing through disk filters with the pore size of 0.45 μm. Speciation of Al forms in aqueous extracts was determined by means of HPLC/IC method (Drábek *et al.* 2003, 2005). This method enables Al forms to be separated into three different groups according to their charge: $Al(X)^{1+}$ {$Al(OH)_2^+$, $Al(SO_4)^+$, AlF_2^+, $Al(oxalate)^+$, $Al(H\text{-}citrate)^+$ etc.}; $Al(Y)^{2+}$ {$Al(OH)^{2+}$, $(AlF)^{2+}$ etc.}; and Al^{3+} {Al^{3+} and transformed hydroxyl Al polymers}. However, $Al(X)^{1+}$ species are coeluted together with $Al(Z)^{\leq 0}$ forms, where Z represents mainly organic ligands. The sum of the fractions in aqueous extracts is assigned Al_{H_2O}.

Micromorphological study. Undisturbed soil blocks were also collected in the studied localities. Collection was realized using steel frames (10 × 5 × 4 cm), which were pushed to the soil pit head. Frames with soil were dried and divided into four parts. Then thin soil sections were prepared from all parts (Catt 1990). The final thin section size was approximately 1.5 by 2 cm. Images were taken with the OLYMPUS BX51 polarization microscope (Olympus Optical, Tokyo, Japan) with the OLYMPUS DP70 digital camera (Olympus Optical, Tokyo, Japan) (using Deep Focus 3.0 software) at a resolution of 300 dpi. Each soil block represented 10 cm of the soil profile where one soil horizon changed to another one. Some of them changed from organic to mineral soil horizons and some of them changed from albic to spodic horizons (see Results and Discussion). The goal of this analysis was to describe features of the ongoing podzolization process.

Soil water retention. Soil water retention curves were studied in the laboratory on undisturbed 100-cm^3 soil samples. Samples were taken from horizons which were thick enough to ensure the soil material homogeneity (e.g. no impact of neighbouring layers). From this point of view the depths of A and Ep horizons were too thin in several cases. The lower number of samples led to excluding these horizons from the statistical analysis. No samples from A horizons could be collected in the case of the grass variant. Two soil samples were usually taken from each horizon. The thickness of the Bhs horizon under the grass cover was insufficient at localities Protržená přehrada and Jizerka. The entire set of soil samples (i.e. from all soil horizons) characterizing forest soils was taken only at Jizerka locality. Soil samples were placed in Tempe cells and saturated with water. Then the samples were drained using several pressure head steps (–10, –30, –50, –100, –200, –350, –600 and –1000 cm). The equilibrium was reached for each pressure head and soil water retention data points were obtained by calculating water balance in the soil sample at each pressure head step of the experiment. It should be mentioned that results were obtained for some soil samples. The reason was that the experiments had to be terminated sooner due to the difficulties to ensure Tempe cells sealing, which was strongly influenced by coarse sandy materials.

RESULTS AND DISCUSSION

Chemical properties

Figure 1 represents average values (calculated for all three sites) of pH_{H_2O}, pH_{KCl}, and eCEC in the soil profiles of both variants (forest and grass). Similar trends of pH distribution in the soil profiles of both variants are indicated. Values of pH_{H_2O} decrease from the F to the Ep and Bhs soil horizon, and then increase with depth. Values of pH_{KCl} are the lowest in organic horizons and then also increase with depth. Differences between variants were studied using the *t*-test. Results of this analysis are presented in Table 2. The value of

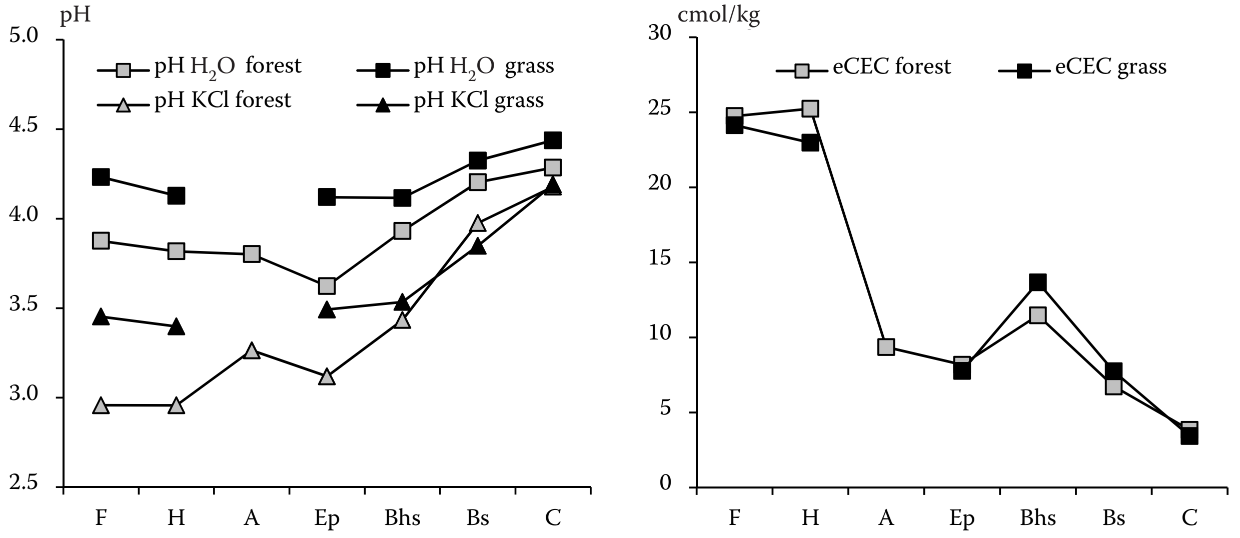

Figure 1. Average values of pH_{H_2O}, pH_{KCl}, and eCEC in different soil horizons and different vegetation cover

pH_{H_2O} is significantly higher in the grass variant in F, H and C horizons. In the case of pH_{KCl} the same difference is apparent only in F and H horizons. Drábek *et al.* (2007) suggested that these differences are results of deforestation and subsequent grass expansion within the studied areas, which happened approximately 30 years ago. The natural ameliorating mechanism occurred in these areas. The distribution of eCEC corresponds to the typical distribution of organic matter (OM) and clay particles as donors of sorption sites in Podzols. Surface horizons with the highest OM amount have the highest eCEC, then eCEC decreases with eluviation to the Ep horizon. Relatively enriched is the Bhs horizon because of accumulation of humic substances and clays in the spodic horizons. The lowest eCEC is in mineral substrate. No significant differences between variants were found (Table 2). The impact of different vegetation cover (forest and grass) on eCEC was discussed in greater detail by Drábek *et al.* (2007). They documented that most sorption sites are occupied in these soils by Al, especially in mineral horizons. Significant saturation of the soil sorption complex with exchangeable base cations (Ca_{ex} and Mg_{ex}) was also found in organic horizons, in mineral horizons it was very low. While Al_{ex} contents in organic horizons were higher for forest than for grass cover, Ca_{ex} and Mg_{ex} contents were lower for forest than for grass cover.

The distributions of Ca and Mg are also similar in the soil profiles of both variants (Figure 2).

Table 2. Results of *t*-test (*t* values; plus values represent the situation that "forest > grass" and minus values conversely) for pH_{H_2O}, pH_{KCl}, eCEC, pseudototal Ca, Mg, Al_{H_2O} and Al_{KCl} contents in different soil horizons

	F	H	Bhs	Bs	C
pH_{H_2O}	−3.368**	−3.109**	−1.659	−1.382	−3.200**
pH_{KCl}	−3.846**	−4.749***	−0.807	1.223	−0.167
eCEC	0.186	0.711	−0.973	−0.601	0.807
Ca	3.144*	−1.728	−2.845*	−1.379	−0.266
Mg	−0.603	−3.413**	−0.712	0.522	0.473
Al_{H_2O}	0.570	2.391*	0.653	−1.091	1.444
Al_{KCl}	1.106	2.909*	−0.407	−0.207	0.070

*, **, ***significant at 0.05, 0.01, and 0.001 probability level, respectively; F – more decomposed material; H – totally decomposed organic material with potential mineral addition (Green *et al.* 1993); Bhs – spodic humus-sesquioxidic; Bs – sesquioxidic horizons; C – substrate horizons

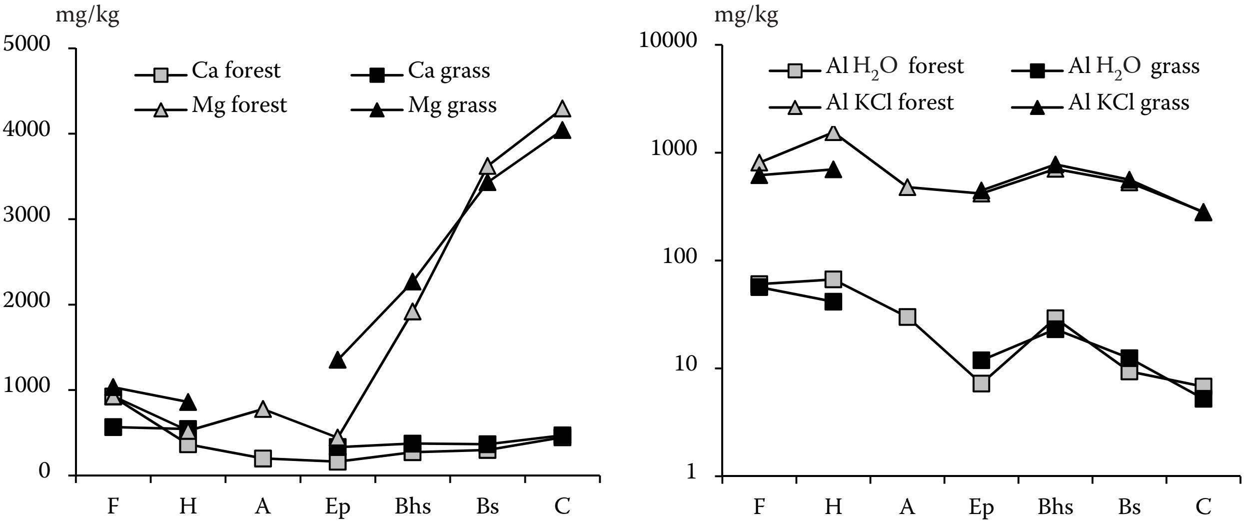

Figure 2. Average values of pseudototal Ca, Mg contents and Al_{H_2O}, Al_{KCl} contents in different soil horizons and different vegetation cover (Y-axis is in a logarithmic scale in the case of Al form contents)

The distribution of elements in the soil profile is connected with their mobility. Ca content rapidly decreases from the F to Ep horizon. In deeper mineral horizons Ca content is low and almost constant. Ca belongs to relatively little mobile elements and its leaching from the surface horizon is very slow. Mg represents a mobile element. Easy transport across the soil profile is a reason why deeper mineral horizons are enriched with this element. Neither Ca nor Mg contents are higher in the Bhs or Bs horizon than in other mineral horizons. Results of *t*-test (Table 2) show a significantly higher amount of Ca in F horizon of the forest variant, and a lower Ca amount in Bhs horizon of this variant in comparison with those of the grass variant. Mg content is significantly lower in Ep horizon of the forest variant in comparison with that of the grass variant. These results do not indicate more favourable conditions in either of the two studied variants.

Figure 2 also shows the distribution of two Al forms extracted with differently strong reagents. An aqueous extract releases only very weakly bound Al. KCl solution releases Al from the sorption complex. Relative depletion of the Ep horizon is evident in both extracts. Also higher contents of Al forms in spodic horizons Bhs and Bs relative to substrate C were found. These find-

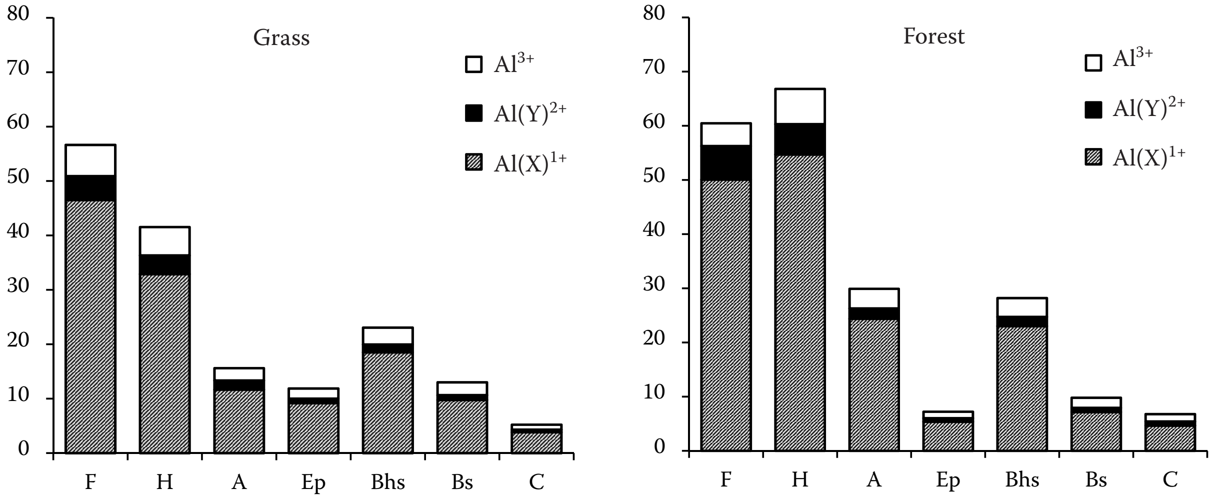

Figure 3. Average values of three Al species (mg/kg) in aqueous extract in different soil horizons and different vegetation cover

ings are typical of Podzols. High contents of both Al forms in H horizon and relatively lower contents in F horizon were determined. An increase of Al content from F to H horizon could be explained by the long-term formation of H horizon and so long-term Al accumulation as it was mentioned above. A significant difference between variants was found only in the H horizon (Table 2). Both types of Al have a higher content in the forest variant. It could be associated with very low pH there. It is important that the majority of the fine roots of vegetation are located in this horizon. So from this aspect the forest sites are more endangered by Al toxicity than the grass sites. As for the podzolization process, no differences were observed in deeper horizons. This indicates similar podzolization intensity.

Figure 3 illustrates the distribution of three Al species separated using an aqueous extract. The largest part of Al in an aqueous extract is composed of $Al(X)^{1+}$ species. It represents around 70% of Al in the extract. $Al(Y)^{2+}$ species accounts for about 10% and Al^{3+} for about 20%. The first two species can be inorganic or can be bound to organic matter, but Al^{3+} represents the real mineral Al form with all its known characteristics, for example high phytotoxicity, which was discussed in greater detail by Drábek *et al.* (2005, 2007). Higher fluctuation of Al contents within horizons is apparent in the forest variant. There are large differences between organic horizons and Ep horizon, then between Ep and Bhs, and also between Bhs and Bs. This larger differentiation of Al distribution in the forest soil profiles could indicate intensive movement of Al within the soil profile (e.g. result of higher podzolization intensity). Contents of particular Al species were similar in most cases in both variants. A significant difference was found in the F horizon, where $Al(Y)^{2+}$ content was higher in the forest variant (*t*-value 2.397*) and in the H horizon, where $Al(X)^{1+}$ and $Al(Y)^{2+}$ contents were also higher in the forest variant (*t*-value 2.361*, 2.827*, respectively).

Micromorphological properties

Figure 4 shows the micromorphological images of soil blocks collected at three sampling sites. The first soil block (Figure 4 left) was collected from the depth of 9–19 cm of the spruce forest soil. This soil block was taken to describe the following soil horizon transition: the humified horizon (H), its gradual transformation to the organomineral humic horizon (A), and A horizon. The highest part of the soil block (a) demonstrates the H horizon. The main part of the image is composed of black granular material. This material is a product of decomposition of needles and roots by the soil organisms of two taxonomic orders (*Acarina*, *Collembola*). Ring features are roots at different stages of decomposition. Undecomposed tissues are visible, and tissues that are completely destroyed and only the black mycorrhizal sheath remained. Practically no mineral compounds are seen. Images (b) and (c) represent the above-mentioned gradual transformation of H horizon to the organomineral humic horizon. The same structure of decomposed organic material as in image (a) is visible, but the fraction of mineral grains increased. Image (d) illustrates the A horizon. This horizon is defined by the fraction of mineral compounds higher than 30% and well decomposed organic material.

The second soil block (Figure 4 in the middle) was collected from the depth of 12–22 cm of the soil covered by grass. This soil block was taken to describe the following soil horizon transition: the humified horizon H (a), transformation to the A horizon (b), A horizon (c), and its transformation to the eluvial albic horizons (Ep) (d). Like in the spruce forest soil, gradual change from H to A horizon (a, b, c) is characterized by an increasing content of mineral grains. However, there is an apparent difference between the structure of organic compounds in the H and A horizons (and transition) of the soil under the grass cover and that in the corresponding horizons of the forest soil. The structure of organic compounds in all samples from the soil under grass is not granular (like in the forest soil), but amorphous. Different microorganisms (the soil organisms of three taxonomic orders at least – *Acarina*, *Collembola*, *Oligochaeta*) decomposed the grass material more than the organisms which decomposed needles in the forest. Different structure of organic and organomineral horizons under spruce and grass cover has an influence on physical properties of soil, for example on pore size distribution and pore connectivity (as it is evident from the images) and consequently on water retention ability (see results below). Image (d) shows the transformation of A to Ep horizon. Release and transport of organic material and Fe oxides lead to colour change to lighter tones, which are visible in the left bottom

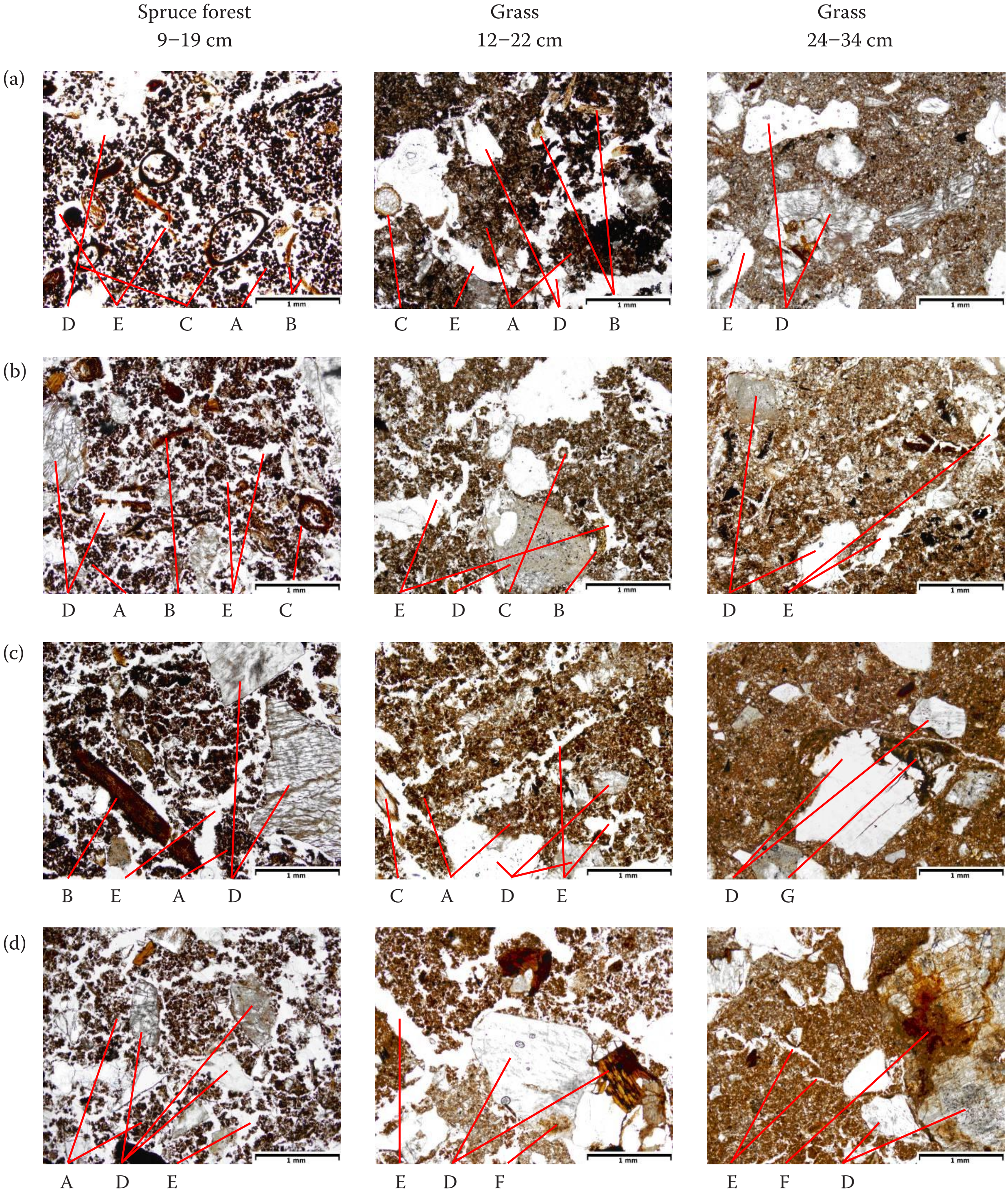

Figure 4. Micromorphological images of the undisturbed soil blocks (divided into four parts); columns represent different horizons and their transformations: left – the humified horizon (H) (a), its gradual transformation to the organomineral humic horizon (A) (b, c), and A horizon (d) in spruce forest soil, middle – the humified horizon H (a), transformation to the A horizon (b), A horizon (c), and its transformation to the eluvial albic horizons (Ep) (d) in soil under the grass cover, right – the Ep horizon (a), its transformation to spodic humus-sesquioxidic horizon (Bhs) (b), Bhs horizon (c), and its transformation to sesquioxidic horizon (Bs) (d) in soil under the grass cover; A – decomposed material, B – not decomposed organic material, C – residues of roots, D – mineral grains, and E – pores, F – Fe presence, G – accumulation of organic matter; all three soil blocks were taken at Jizerka locality

corner of the image. Weathering and release of Fe oxides from stones are also visible in this image as red-brown fuzzy coating on the stone surface. Similar micromorphological features of H horizons were documented for the soil under the spruce forest and grass cover by Kodešová *et al.* (2007).

The last undisturbed soil block, which is presented here (Figure 4 right), was collected from the deeper part of the soil profile (24–34 cm) under the grass cover. This undisturbed soil block was taken to describe the ongoing fast podzolization process, which is documented on thin soil horizons and their transitions as follows: the Ep horizon (a), its transformation to spodic humus-sesquioxidic horizon (Bhs) (b), Bhs horizon (c), and its transformation to sesquioxidic horizon (Bs) (d). Horizons and their changes are apparent again. The Ep horizon ((a) and top part of (b)) is grey or light brown, because of depletion of the organic matter and iron oxides. The Bhs horizon (bottom part of (b) and (c)) is dark brown. Mainly brown humic substances are precipitated here. The Bs horizon (central and bottom part of (d)) is red-brown. Mainly red iron sesquioxides are precipitated there. In the Ep horizon, the release of Fe oxides is seen as well as in the Ep horizon shown in the middle of Figure 4. Accumulations of humic substances on the top of mineral grains are evident in the Bhs horizon. Percolation of humic substances and subsequent Fe oxidation in the grain cracks are

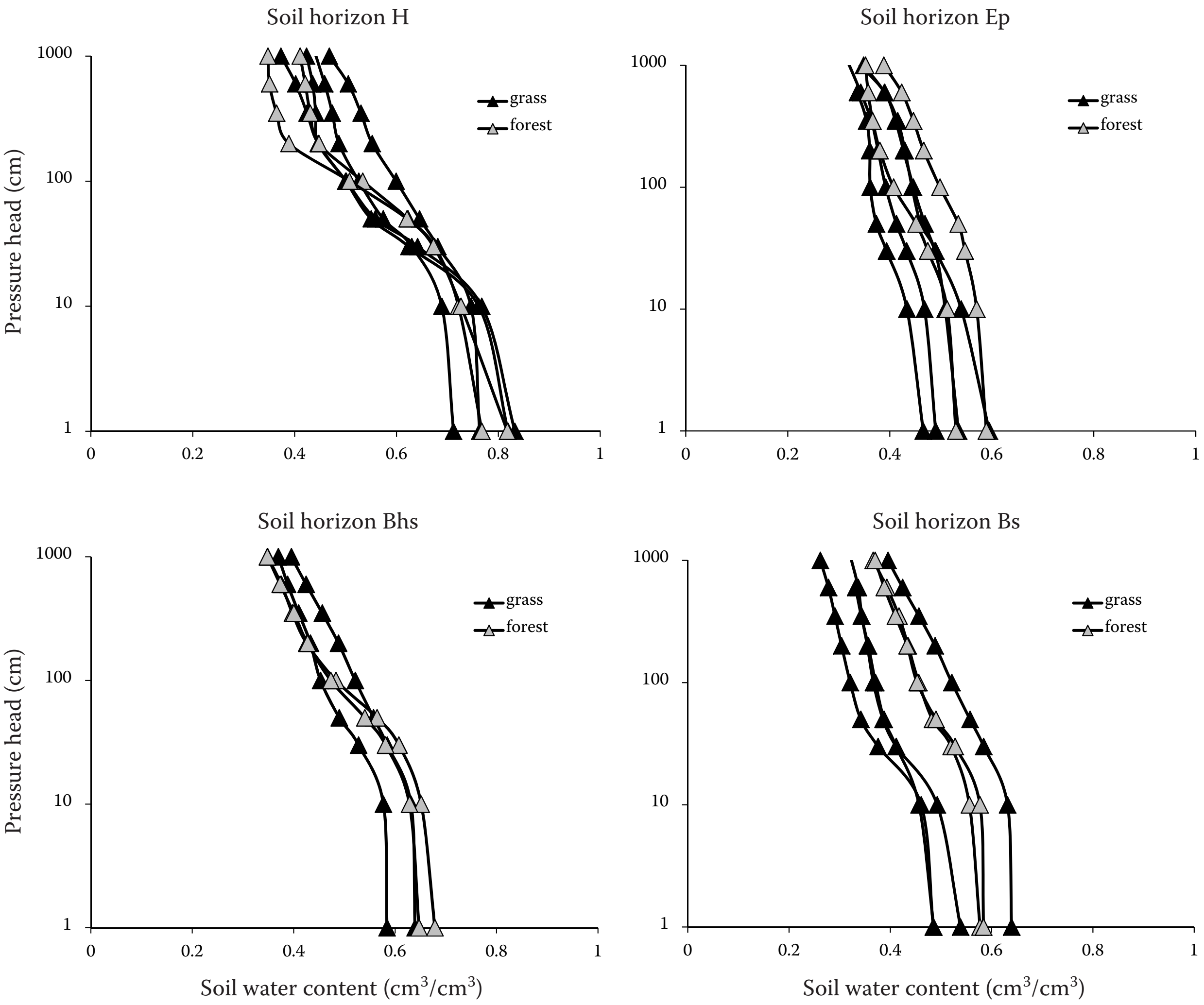

Figure 5. Soil water retention curves obtained in the soil samples characterizing different soil horizons under different vegetation cover. All samples from forest were taken at Jizerka locality (which was the only place where it was possible to take soil samples from all soil horizons); samples taken under the grass cover were collected at localities Jizerka (2 samples per each layer except Bhs horizon), Kristiánov (2 samples from Bhs horizon and 1 per another layer) and Protržená přehrada (1 sample per each layer except Bhs horizon)

also noticeable. Images clearly illustrate the early stage of podzolization process, which resulted in thin soil horizons (Lundström *et al.* 2000; Alexandrovskiy 2007; Sauer *et al.* 2007). The soil profile diversification (soil properties and micromorphological features) indicates also the fast podzolization process as discussed by Stützer (1998) and Caner *et al.* (2010).

Soil water retention

Figure 5 shows the soil water retention curves obtained in the soil samples characterizing different soil horizons under different vegetation cover. It should be mentioned that in many cases it was not possible to take undisturbed soil samples due to the insufficient thickness of soil horizons. Generally, the highest saturated soil moistures were observed in organic horizons of the studied soil profiles. On the contrary, the lowest saturated soil moistures were found in eluvial albic horizons (Ep). While the shape of the soil water retention curves in Ep and Bs horizons under different vegetation cover was very similar, it was different in H and Bhs horizons. The curvature of the S-shaped retention curves obtained in soil samples from the spruce forest was noticeably larger than that in soil samples taken under the grass vegetation. While the saturated soil water content was similar in both soils (grass and spruce), the soil water contents corresponding to pressure heads of −100 cm and smaller were lower in soils under the spruce forest than those in soils under the grass cover. This corresponds to the character of organic matter in the soil horizons H and Bhs, which was documented on micromorphological images (Figure 4). A greater difference between the soil water retention curves measured in H horizons under the spruce forest and grass cover was documented by Kodešová *et al.* (2007). While the soil water retention curves for organic material under the spruce forest were similar to curves presented here, the curves measured for organic material under the grass vegetation showed noticeably larger retention ability than curves presented here. The entire organic matter horizon (i.e. L, F and H) under the grass studied by Kodešová *et al.* (2007) was significantly thicker than horizons sampled in this study. The reason may be greater decomposition of organic material and larger material consolidation in the H horizon in the study by Kodešová *et al.* (2007) than that in the study presented here. Nevertheless, the greater retention ability of soil samples taken under the grass compared to those under the spruce was documented in our study.

CONCLUSIONS

This study was focused on the Podzol soil type and on differences in chemical properties, micromorphological features and retention ability in this soil type covered by different vegetation, particularly grass and spruce forest. It was shown that larger differences in the studied chemical properties (pH_{KCl}, pH_{H_2O}, eCEC, content of Ca, Mg, Al_{KCl}, Al_{H_2O}, $Al(X)^{1+}$, $Al(Y)^{2+}$ and Al^{3+} species) were in the surface organic horizons and they decreased with depth. It was however also documented that podzolization intensity is higher under spruce forest. Better soil conditions, exhibited as lower concentration of most mobile Al species and higher pH values were recorded on the areas covered by grass in comparison with those under the forest cover. Generally, grass expansion on clear-cut areas (which occurred 30 years prior to our study) as a natural amelioration step results in the particular restoration of soil conditions in the regions strongly affected by anthropogenic acidification. The micromorphological features studied on the soil thin sections using the optical microscope and soil water retention curves measured on the undisturbed 100 cm^3 soil samples showed a significant influence of the organic matter presence on the soil structure and retention ability of H and Bhs horizons. Soil under the grass cover had denser structure (e.g. different pore-size distribution). Soil samples under grass contained a greater fraction of small capillary pores compared to that in soil samples under spruce forest. As a result, the higher retention ability of soil under grass than that of soil under the spruce forest was documented. Interestingly, very similar retention curves were measured in the Ep and Bs horizons under both vegetation covers. Finally, micromorphological features studied on the thin soil sections clearly documented a podzolization mechanism (e.g. organic material transport and its accumulation, weathering process and Fe oxidation and mobilization).

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