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Tree layer disintegration and its impact on understory vegetation and humus forms state in the Šumava National Park

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Abstract

This paper presents preliminary results of the research carried out in the Šumava National Park. It describes changes in understory vegetation development and the state of ectorganic (holorganic) layers in forest soils that follow spruce forest dieback caused by bark beetle calamity. Ecological factors on forest sites are influenced by the tree layer declining. The cover degree, understory vegetation species structure and the state of particular ectorganic horizons are undergoing substantial changes. Preliminary phytosociological surveys were evaluated according to Ellenberg's ecological factors method. There were used both, the International and Czech classification systems, to describe morphological state of ectorganic horizons. During two-year research period, there were documented changes in understory vegetation cover and species composition. Humus forms show high variability and the character of ectorganic horizons varies in short distance according to particular site conditions.

Key words: declining of tree layers, site conditions changes, cover and species structures of understory vegetation, humus layer, humus form classification

Introduction

There was observed rapid declining of the Norway spruce forests in some areas of the Šumava National Park over the last three decades. The bark beetle calamity and windthrow disaster together with the air pollution and improper management are the most serious problems, which harm stability and sustainability of these valuable forest ecosystems (Zatloukal 1998, Vinš 1999).

The changes in biotic and abiotic properties of forest sites follow declining of the tree layer (Vogt et al. 1986, Jurgensen et al. 1990, Linhart 1999, Vacek et al. 1999). Higher amount of solar radiation reaches the soil surface and increases its temperature (the understory vegetation and top holorganic layers under the declined forest receive considerably higher amount of soil radiation than in the living forest stands). The soil moisture status is changing due to decreased tree transpiration and interception. In the deteriorated forest, the surface and ground water run off show different pattern in comparison with the vital forest stand (Kuřík et al. 1999). The clear-cut adverse effects on the forest floor state and development were presented in many studies. According to Emmer (1999), changed moisture and temperature conditions in the upper organic horizons may strongly influence the microbiological activity rate and consequently also the rate of the organic matter decomposition and mineralization. On the cut sites there were also shown higher rates of the microbial activity, increased organic matter decomposition and nutrient availability (BINKLEY 1984, KLIMO & KULHAVÝ 1994, SVOBODA & PODRÁZSKÝ 2002). Increased temperature and biological activity in the topsoil layers influence the rate of organic matter decomposition (PODRÁZSKÝ 1999b). Altered forest site conditions are followed by the changes in plant formation (understory vegetation cover degree and species composition) (SOUKUPOVÁ 1996, LINHART 1999, VIEWEGH 1999). Understory vegetation development depends on the dominant tree layer arrangement and differs in natural forest ecosystems and forest ecosystems influenced by human activity.

The state of ectorganic horizons under the declined tree layer is highly influenced by understory vegetation dynamics and altered forest site conditions. Changes of humus horizons physical and chemical properties often follow transformed thickness and modified biological activity rate of topsoil layers. Forest soils on extreme sites are endangered by erosion processes especially after original forest dieback (PODRÁZSKÝ & ŠACH 1992, ŠACH & PAŠEK 1996, PODRÁZSKÝ 1999b).

The origin of particular humus form is based on the forest site conditions. Humus forms highly influence the nutrient cycling, moisture and temperature of the topsoil layer and also provide habitat for the fine roots of the forest trees and vegetation (PODRÁZSKÝ 2001). As such, humus forms are an important factor of the forest site productivity. This role and the relationship between humus forms, vegetation, and soil recognized in many studies, designates humus forms as a principal components of forest ecosystem (GREEN et al. 1993, SEVINK 1997). Humus forms also represent the part of soil profile, which is most of all, exposed to disturbances. From this point of view it is essential to understand the way in which the dynamics changes of ectorganic horizons influence the forest community, soil and consequently the whole ecosystem productivity and sustainability.

MATERIAL AND METHODS

Selection of the plots and their general characteristics

Research plots were selected in location on the Trojmezná Mt. (Šumava National Park). With respect to the area extend (about 600 ha), research plots (33 plots total) were established in the compartment 47a and 48a. These compartments show the highest breakage dynamics in comparison to the other parts of this area. Plots were established during summer 1998 and their locations were posted in forestry maps. Concerned area is situated in the Norway spruce altitudinal zone and its altitude ranges from 1210 m a.s.l. to 1350 m a.s.l. The average annual air

Table 1. List of soil pits - their general information and location

Plot	Pit	Altitude(m)*	Forest type set*	Substrate	Soil type
9b	I	1295	8N – Acidic spruce on stones	Biotite granite	Leptosol/Podzol
23	II	1250	8Y – Skeletal spruce	Biotite granite	Lithic Leptosol
25	III	1235	8Y – Skeletal spruce	Biotite granite	Lithic Leptosol
22	IV	1280	8S – Mesic spruce	Biotite granite	Cambisol/Podzol
30	V	1260	8S – Mesic spruce	Biotite granite	Dystrict Cambisol
Transect	VI	1275	8K – Acidic spruce	Biotite granite	Podzol/Leptosol
Transect	VII	1210	8V – Wet spruce with sycamore	Biotite granite	Podzol/Histosol

*) Data apply to forest stand specified according to typological map and forest management plan of zone I. Trojmezná Mt. – Šumava National Park.

temperature is about 3.5°C; average annual rainfall is close to 1200 mm. Parent rock consists of biotite granite. Table 1 gives an overview of soil types.

Plant communities in the research area are mostly composed from these forest sites (thereinafter as f.s.): 8Y – skeletal spruce, 8N – acidic spruce on stones, 8S – mesic spruce, 8V – wet spruce with sycamore and 8K – acidic spruce forest sites (VIEWEGH 2000). Forest community estimated age varies between 200–300 years. Forest ecosystems in this area represent the most valuable relics of natural mountain forests in the Czech Republic (PRŮŠA 1990).

Phytosociological survey

Research plots were selected with the intention to cover all stages of forest stands development on various site classes (forest types set). There were recognized three types of localities:

- areas with vital and living relics of forest stands,
- areas with declining forest stands in various disintegration periods,
- clear-cuts created by forest management intervention.

Phytosociological survey was carried out using standard forest methods (RANDUŠKA et al. 1986, VIEWEGH 1999). Vegetation surveys were done through July 1998 and July 2000. Taxonomic classification of the tree layer and understory vegetation was set up according to (DOSTÁL 1989); taxonomic classification of moss layer was set up according to ELLENBERG et al. (1999). Original surveys were archived and this paper presents only of the vegetation surveys results. For preliminary data evaluation, there were used the reference of the plant species to the ecological factors in middle Europe conditions, called Ellenberg's scale (ELLENBERG et al. 1999). Indexes of ecological factors are often used as an operative tool that enables rapid evaluation of vegetation surveys, but it does not substitute more accurate evaluation methods. The method of Ellenberg's ecological factors is convenient for seeking significant ecological factors for individual forest sites (ELLENBERG et al. 1999).

Morphological survey of ectorganic soil layers

Morphological description of holorganic horizons and the state of humus forms was carried out on selected number of research plots. There were selected research plots representing particular forest classes (forest type set), as well as areas with declined and living tree layer. Humus forms represent individual parts of the forest ecosystem, which show maximal variability (PODRÁZSKÝ 2001, GREEN et al. 1993). Therefore description of humus forms in the study has to be done in extended dimensions on more plots (GREEN et al. 1993, EMMER 1998, PODRÁZSKÝ 2001). On 22 selected research plots, there were marked 5 m long transects. Soil profiles were uncovered in depth given by thickness of holorganic horizons and horizons A on every 0.5 m of transect. In this manner, there were dug 11 soil pits on selected plots; the width of particular soil pit varied between 25 and 30 cm. Thickness and order of soil layers L, F, H, and A were described as well as dominant plant species growing on the soil pits. There were determined master horizons and subordinate horizons important for specification of particular humus forms. International classification system (GREEN et al. 1993) and Soil classification system used in Czech Republic (VOKOUN 2000) were applied to determine particular humus forms on the research plots. Field records were processed using graphic software; humus forms, thickness and order of ectorganic horizons, as well as dominant plant species were matched with sampled soil profiles.

RESULTS AND DISCUSSION

Phytosociological survey

Species composition of understory vegetation on the research plots is relatively poor and monotonous. Plant species *Calamagrostis villosa*, *Athyrium distentifolium*, and *Vaccinium myrtillus* are the most frequent and the most dominant species of plant community on the research plots. These plant species often form large monocenosis and their occurrence depend on ecological conditions of individual forest sites. On extreme stony forest sites with low thickness of soil profile, moss species form considerable part of the plant cover. Understory vegetation cover is close to 100% on all research plots. This feature probably bears on lower competitive ability of the tree layer in high mountain altitude (Norway spruce altitudinal zone) as well as on history of these forest stands.

Concerning the results of vegetation surveys, it appears that changes in vegetation development have rather quantitative than qualitative character. Understory vegetation dynamics showed the largest changes on these forest sites: mesic spruce f.s. (8S), acidic spruce f.s. (8K) and acidic spruce on stones f.s. (8N). Especially cover of species *Calamagrostis villosa* was slightly increased on some plots with declined tree layer. On plot No. 16 species *Calamagrostis villosa* shows higher cover degree on areas where the tree layer has been damaged by windthrow in comparison to plots on similar forest sites. Typical clear-cut species as *Rubus idaeus* and *Chamerion angustifolium* have begun to appear on areas with declined tree layer, mostly around standing dead trees. Species *Vaccinium myrtillus*, *Polytrichum formosum*, and *Sphagnum* spp. compose dominant part of the vegetation cover on the skeletal spruce f.s. (8Y). These forest sites have extreme character; they are found on steep extreme stony slopes with shallow soils, where the soil profile is mostly composed of stony debris and ectorganic horizons. Mineral horizons usually occur in limited scale there. Soil profile on these localities is strongly determined by an existence of tree layer and understory vegetation root system, as it holds ectorganic horizons on surface of stony debris. Plant species growing on these extreme forest sites belong among stress tolerant plants; the limiting ecological factors are nutrient sources and shallow soil profile. Similar results concerning vegetation dynamics on extreme skeletal forest sites were also determined in other parts of Czech Republic. VACEK et al. (1999) presents that introskeletal erosion and changed light conditions under declined tree layer have the highest influence on development of understory vegetation on extreme skeletal forest sites. The results concerning development of the ground layer on localities with declined tree layer correspond with data found in available literature. SOUKUPOVÁ (1996) presents strong expansion of specie *Calamagrostis villosa* on clear-cuts in mountain forest ecosystem. VIEWEGH (1999) presents the expansion of species *Avenella flexuosa* and *Calamagrostis villosa* as well as appearance of species *Rubus idaeus* and *Chamerion angustifolium* on the clear-cuts and areas with declined tree layer in the spruce forest located in the Šumava National Park. LINHART (1999) presents only quantitative changes of understory vegetation following tree layer declining in the spruce forest located in the same area.

Conclusive values of Ellenberg's ecological factors

For further understory vegetation development, there were found these most significant ecological factors: light, soil nitrogen and soil reaction. The evaluation results are archived by author of this paper. With regard to the volume of this paper, tables of the conclusive values were not published and are available on request.

Light

This ecological factor almost did not vary on the research plots. Value of light index was slightly higher only on the localities with increasing cover of species *Calamagrostis villosa* and *Avenella flexuosa*. SOUKUPOVÁ (1996) and VACEK et al. (1999) present changes of the light conditions on forest sites as one of the most important factor for understory vegetation dynamics. Clear-cut species as *Calamagrostis villosa* and *Avenella flexuosa* have the highest value of light index among all plant species found on research plots. Changed light conditions on research plots with declined tree layer should contribute to the expansion of quoted clear-cut species.

Soil nitrogen

Dynamics of soil nitrogen on the research plots was influenced by the expansion of clear-cut species under declined tree layer. Research plots with unaltered development of understory vegetation did not show any changes in the content of soil nitrogen. Soil nitrogen content was slightly changed on the plots No. 4, 7, 16, 20, and 30 due to the expansion of species *Calamagrostis villosa*. Tree layer on the latter mentioned plots died back and the cover of specie *Calamagrostis villosa* increased by 5–10%. SOUKUPOVÁ (1996) presents that dynamics of the nitrogen is an important factor that influences the clear-cut species expansion on forest sites in Giant Mts. NOVÁK (1999) also presents that disintegration of the spruce tree layer followed by expansion of herbaceous vegetation is in mutual interactions with nitrogen dynamics.

Fig. 1 gives an overview of the soil nitrogen conclusive values for individual research plots. Plant species on the mesic spruce (8S) and wet spruce with sycamore (8V) forest sites indicate noticebly higher content of soil nitrogen than plant species on skeletal spruce (8Y) and acidic spruce on stones (8N) forest sites. The soil nitrogen is an important ecological factor, which distinguishes individual forest sites in the concerned area. According to this ecological factor, skeletal spruce (8Y) forest sites belong to the group of poor forest soils; this fact corresponds with soil examination (see Table 1). On the other hand, according to the content of soil nitrogen, mesic spruce (8S) forest sites belong to the group of medium nutrient soils (see Table 1).

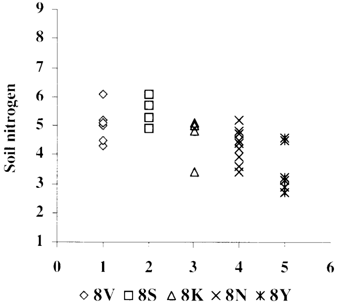

Fig. 1. Conclusive values of ecological factor – soil nitrogen on research plots and forest sites.

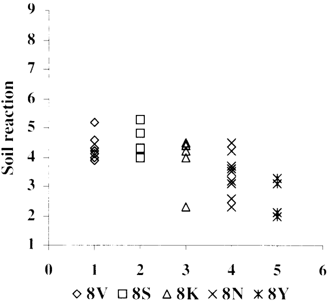

Fig. 2. Conclusive values of ecological factor – soil reaction on research plots and forest sites.

Soil reaction

Under declined tree layer, soil reaction dynamics was influenced by the expansion of clear-cut species and corresponded with soil nitrogen dynamics. This ecological factor did not show any changes on research plots with unaltered development of understory vegetation. Fig. 2 gives an overview of the soil reaction conclusive values for individual research plots. Plant species indicate strong differences between the soil reaction values on individual forest sites. For an example according to this ecological factor the skeletal spruce (8Y) forest sites belong to the group of extremely acid or acid soils according to this ecological factor. This fact corresponds with soil examination results (see Table 1) and confirms the extreme character of skeletal localities.

Morphological survey of ectorganic soil layers

Figs. 3–6 represent graphical visualization of four selected humus profiles. Graphical visualizations of all the sampled humus profiles were archived by the author. Concerning the results of humus forms survey Hemimor is the most widespread humus form on the research plots. The Hemimor is typical for the acidic spruce on stones (8N) and acidic spruce (8K) forest sites. Table 3 and Fig. 3 give an example of the Hemimor humus form on plot No. 13. The horizon Fm is diagnostic for this humus form (Green et al. 1993) and its thickness is noticeably greater than the thickness of horizon Hr. Dominant horizon Fm indicates slow rate of the organic matter decomposition as well as accumulation of the organic matter on the soil surface. The fungal hyphae that are abundant in this horizon carry out most of the decomposition of the plant residues. Dominant horizon Fm is typical for Hemimor. On the other hand, horizon H (type Hr or Hh) (Green et al. 1993) also forms part of the soil profile. The character of the horizons H depends on forest sites conditions and dominant plant species.

Hemimor and optionally Resimor are typical humus forms for the skeletal spruce (8Y) forest sites. Table 4 and Fig. 4 give an example of the humus forms on the plot No. 25. Diagnostic horizon Fm indicates slow rate of the organic matter decomposition and its accumulation on the soil surface; humification horizon is an Hr type (Green et al. 1993). In most cases mineral horizon Ah in most cases does not form part of the soil profile and therefore the holorganic horizons are in direct contact with the parent material. Thickness of the holorganic horizons ranges from 8 to 14 cm and just as an exception debris it exceeds 20 cm in spaces between coarse. In these spaces, horizon Hr looses its continual character and forms rather fractions of amorphous organic matter mated to roots of trees and understory vegetation. As a result, the soil organic matter characteristics as well as understory vegetation dominant species (*Vaccinium myrtillus*, *Polytrichum formosum*, and *Sphagnum* spp.) indicate that those forest sites (skeletal spruce – 8Y) are endangered by rapid mineralization of organic matter, which follows the tree layer disintegration.

ŠACH & PAŠEK (1996) present similar result from research carried out on the block fields (Lithic Leptosol connected with 8Y, 8Z and partly also with 8N forest sites) in the Giant Mts. These extreme localities were endangered by introskeletal erosion (organic and mineral soil parts run off between spaces of coarse debris that is related to degradation of vegetation and organic matter rapid mineralization), especially after the tree layer disintegration. Table 2 overviews the area of individual forest types in compartment 47 and 48 in the Trojmezná Mt. location. Concerning the results of this research and other findings from different parts of the Czech Republic (ŠACH & PAŠEK 1996, EMMER 1999, PODRÁZSKÝ 1999a, 1999b), the sets of forest types 8Y and 8Z belong to the group of localities that are highly endangered with introskeletal erosion and connected processes. These localities placed on extreme steep slopes made of granite coarse debris have got vegetation cover formed mainly by species *Vaccinium myrtillus* and moss layer and cover about 10% of the study area (Table 2). The root system of trees and understory vegetation is an important factor for sustainability of the soil profile on afore mentioned localities. The root system forms compact net on the surface of coarse debris (block fields) that enables and supports the soil profile existence. Following tree layer disintegration and altered site conditions, modified biological activity and soil organic matter rapid mineralization may totally destroy the soil profile (ŠACH & PAŠEK 1996, EMMER 1999, PODRÁZSKÝ 1999a, 1999b).

Concerning the humus forms survey results the Humimor is second most widespread humus form. It forms most of the soil profile on the wet spruce with sycamore f.s. (8V) and mesic spruce f.s. (8S). Diagnostic horizons Fm and Hh (GREEN et al. 1993) are typical for this humus form. Distinct horizon Hh that has noticebly greater thickness than horizon Fm distinguishes humus form Humimor from Hemimor. Tables 5, 6 and Figs. 5, 6 give the examples of the humus form Humimor on the research plots No. 1 and 29. Well-developed horizon Hh of Humimor indicates relatively higher rate of the organic matter decomposition as well as higher rate of nutrient turnover in the soil profile in comparison with the humus form Hemimor. Humimor appears to be found on forest sites with rather deeper soil profile and lower coarse debris content. Hemimor on the other hand appears to be found on forest sites with rather shallow soil profile and with higher coarse debris content.

Table 2. Area (ha) of forest type sets in compartments 47 and 48 in the Trojmezná Mt. location (Šumava National Park).

Forest type set	Land area (ha)	% of total area
8V – Wet spruce with sycamore	35.9	22
8S – Mesic spruce	23.7	15
8K – Acidic spruce	36.6	23
8Y – Skeletal spruce	16.4	10
8Z – Spruce with rowan	2.1	1
8N – Acidic spruce on stones	46.0	29
Total	**160.7**	**100**

There were found some close relationships between the humus forms and understory vegetation. Plant species *Vaccinium myrtillus*, *Avenella flexuosa* and some species of mosses grow usually on forest sites characterized by shallow soil profile (low thickness of ectorganic horizons) and higher coarse debris content. On the other hand, species *Luzula sylvatica*, *Athyrium distentifolium*, and *Calamagrostis villosa* often prefer forest sites with higher thickness of ectorganic horizons and favourable conditions of organic matter turnover. VACEK et al. (1999) presents similar results concerning relations between thickness of the soil profile and understory vegetation species composition in the Giant Mts. Results of the humus soil survey also correspond with results of vegetation survey. For example plant species growing on the skeletal spruce forest sites (8Y) indicate extreme ecological conditions. Values of the soil nitrogen and soil reaction that were determined on these localities are very low and indicate unfavourable conditions for the organic matter turnover and nutrient cycling. Humus form and character of the ectorganic horizons detected there correspond with the results of vegetation survey. Hemimors or Resimors with dominant horizons Fm are mostly found on the skeletal spruce (8Y) forest sites (see Table 3, and Fig. 3) and indicate slow rates of humification of organic materials. On the other hand, plant species ranging on the wet spruce with sycamore (8V) and mesic spruce (8S) forest sites indicate different dynamics. Values of the soil nitrogen and soil reaction (Figs. 1 and 2) determined on these forest sites are higher than on the skeletal spruce (8Y) forest sites and indicate quite favourable conditions for organic matter turnover and nutrient cycling. Humimor with its dominant horizon Hh mostly found on these localities indicates an intensive rate of synthesis and accumulation of the humus material in the soil profile.

There were found no considerable differences in the character and thickness of the individual ectorganic horizons between localities with declined tree layer and localities with living vital forest stands. Development of the ectorganic horizons on research plot No. 10 is an exception. Due to clear-cut site conditions on this plot (about 10–15 years) the thickness of ectorganic horizons was slightly decreased in comparison to the thickness of ectorganic horizons on plots with similar site conditions. Changes of the morphological properties in ectorganic horizons, which follow altered site conditions, take place in long-term period. High variability of humus forms on research plots would need more accurate methods of the humus forms survey and especially of its evaluation.

There was confirmed generally large spatial variability of the humus forms in the concerned area. This fact corresponds with data presented in available literature. Changes of the thickness and morphological properties of individual holorganic horizons in the short distances within one forest site are common. More distinct differences in character of humus forms are noticeable between individual forest sites. The character of individual diagnostic humus horizons is also altered according to changing forest site conditions. This means that specific ecological forest site conditions directly influence the origin of individual humus forms. GREEN et al. (1993) and PODRÁZSKÝ (2001) present that biological factors create ecological variability within borders of biocenose and therefore create different kinds of habitats as well as influence development of humus forms on relatively small sites.

CONCLUSIONS

Phytosociological survey

Based on the two-year study period, the trends in the understory vegetation dynamics in concerned area are inconclusive. Succession changes in the plant community composition take place in long-term period and therefore the vegetation surveys should be repeated few more times. On the basis of existing results there were made only preliminary conclusions indicating that vegetation dynamics changes have rather quantitative than qualitative character. Clear-cut species *Rubus idaeus* and *Chamerion angustifolium* emerged on the localities with declined tree layer, but their total cover degree on the research plots is minimal. Cover of species *Calamagrostis villosa* and *Avenella flexuosa* was slightly increased on a few research plots; their further expansion should depend on the particular forest site conditions. The ecological factors as soil nitrogen and soil reaction (according to Ellenberg's ecological factors method) are significant and distinguish individual forest sites.

Morphological survey of ectorganic soil layers

During the two-year study period, there were found no significant changes in character and thickness of ectorganic horizons. Ectorganic horizons thickness was slightly decreased only on research plot No. 10. Hemimor is prevailing humus form on most of research plots and is followed by Humimor and Resimor. There was documented retarded organic matter decomposition (gathered on the soil surface) in horizon F (in case of Hemimor and Resimor) and in horizon H (in case of Humimor). The survey of humus forms confirmed large spatial variability of individual ectorganic horizons. Changes of thickness and morphological properties in short distances are typical and respond to the ecological site conditions. On some research plots (mostly on skeletal spruce f.s. and optionally also on acidic spruce on stones f.s.) the ectorganic horizons form an essential part of the soil profile and condition forest ecosystem sustainability. Vegetation survey results are in close relationship with result from the humus forms survey. Rather favourable soil conditions found on the mesic spruce f.s. (8S) and wet spruce with sycamore f.s. (8V) were confirmed by humus forms survey. Extreme ecological and soil conditions on the skeletal spruce f.s. (8Y) found during the vegetation survey correspond with results of humus forms survey.

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List of used abbreviated terms (Tables 3–6 and Figs. 3–6): Lv –upland litter horizon, F1m – upland fermentation mycogenous horizon, F2m – upland fermentation mycogenous horizon, Hr – upland residues humus horizon, Hh – upland humic humus horizon, Ah – mineral horizon enriched with organic matter, St – soil skeleton (stones, debris), Mh – mineral horizon, w – horizon containing significant amount of coarse woody debris.

Table 3. Description of humus profile on research plot No. 13, forest type set 8N – acidic spruce on stones. Particular humus form is Hemimor (GREEN et al. 1993) or Typical Mor (VOKOUN 2000). Investigated profile is located in Šumava National Park (Zone I. Trojmezná Mt.). It has developed on biotitic granite. Lithic Leptosol and optionally Stony Podzol associated with acidic spruce on stones (*Picea abies* – *Vaccinium myrtillus* – *Calamagrostis villosa*) forest community. See GREEN et al. (1993) for explanation of used abbreviated terms.

Horizon	Thickness (cm)	Description
Lv	0–1.5	Forest litter mostly composed of leaves of *Vaccinium myrtillus*, *Calamagrostis villosa* and needles of *Picea abies*, small sized fragments of branches, apparent color changes, moist, no roots, loose.
F1m	1.5–4.5	Moist, loose character, abundant fibrous plant fragments, common fungi mycelium, common roots.
F2mw	4.5–7.5	Moist, non-compact matted structure, abundant fungi mycelium, common roots, abundant decayed wood.
Hhw	7.5–12	Moist, dark color, massive blocky structure, pliable consistence, common fungi mycelium, gritty character, common root, abundant decayed wood.
Ah	12–13	Rather massive, it is followed by mineral horizons.

Table 4. Description of humus profile on research plot No. 25, forest type set 8Y – skeletal spruce. Particular humus form is Hemimor (Resimor) (GREEN et al. 1993) or Shallow mor (Vokoun, 2000). Investigated profile is located in Šumava National Park (Zone I. Trojmezná Mt.). It has developed on biotitic granite. Lithic Leptosol associated with skeletal spruce (*Picea abies* – *Vaccinium myrtillus*) forest community. See GREEN et al. (1993) for explanation of used abbreviated terms.

Horizon	Thickness (cm)	Description
Lv	0–1	Forest litter mostly composed of leaves of *Vaccinium myrtillus* and needles of *Picea abies*, small sized fragments of branches, apparent color changes, moist, no roots, loose.
F1mw	1–4.5	Moist, loose character, abundant fibrous plant fragments, common fungi mycelium, fine roots, common decayed wood.
F2mw	4.5–7	Moist, moderate non-compact matted structure, abundant fungi mycelium, common roots, and abundant decayed wood.
Hrw	7–8.5	Moist, dark reddish brown, weakly blocky structure, discernible plants fragments, abundant decayed wood, common fungi mycelium, concentrated around roots, generally fragments of horizon H.
Ah	–	Thin, featureless, mineral horizons are absent in most cases.

Table 5. Description of humus profile on research plot No. 1, forest type set 8V – wet spruce with sycamore. Particular humus form is Humimor (Green et al. 1993) or Mull mor optionally Moist peaty mor (Vokoun 2000). Investigated profile is located in Šumava National Park (Zone I. Trojmezná Mt.). It has developed on biotitic granite, Histosol optionally Humus Podzol associated with wet spruce with sycamore (*Picea abies – Athyrium distentifolium – Luzula sylvatica*) forest community. See Green et al. (1993) for explanation of used abbreviated terms.

Horizon	Thickness (cm)	Description
Lv	0–1.5	Forest litter mostly composed of leaves of *Athyrium distentifolium*, *Luzula sylvatica* and needles of *Picea abies*, apparent color changes, moist, loose, initial fragmentation.
F1m	1.5–5.5	Moist, loose, abundant fibrous fragments of plants, non-compact matted structure, common fungi mycelium.
F2m	5.5–10	Wet, compact matted structure, pliable consistence, abundant fungi mycelium and roots.
Hh	10–25	Wet, dark black color, compact matted structure and resilient consistence, greasy, abundant fungi mycelium, abundant fine and medium roots.
Ah	26–27	Rich in organic matter, it is followed by mineral horizons.

Table 6. Description of humus profile on research plot No. 29, forest type set 8S – mesic spruce. Particular humus form is Humimor (Green et al. 1993) or Mull mor (Vokoun 2000). Investigated profile is located in Šumava National Park (Zone I. Trojmezná Mt.). It has developed on biotitic granite, Dystrict Cambisol optionally Podzol associated with mesic spruce (*Picea abies - Luzula sylvatica - Athyrium distentifolium – Calamagrostis villosa*) forest community. See Green et al. (1993) for explanation of used abbreviated terms.

Horizon	Thickness (cm)	Description
Lv	0–1.5	Forest litter mostly composed of leaves of *Athyrium distentifolium*, *Luzula sylvatica* and needles of *Picea abies*, apparent color changes, moist, loose, initial fragmentation.
F1m	1.5–3.5	Moist, loose, abundant fibrous fragments of plants, non-compact matted structure, common fungi mycelium.
F2m	3.5–5.5	Moist, compact matted structure, pliable consistence, abundant fungi mycelium and roots.
Hh	5.5–11	Moist, dark black color, compact matted structure and resilient consistence, greasy, abundant fungi mycelium, abundant fine and medium roots.
Ah	11–13	Rather massive, it is followed by mineral horizons.

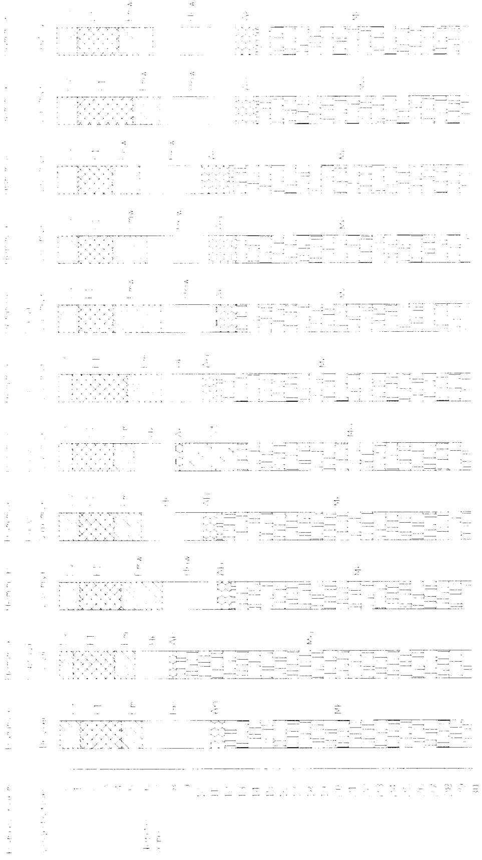

Fig. 3. Humus profile on research plot No. 13. Legend: See GREEN et al. (1993) for explanation of used abbreviated terms.

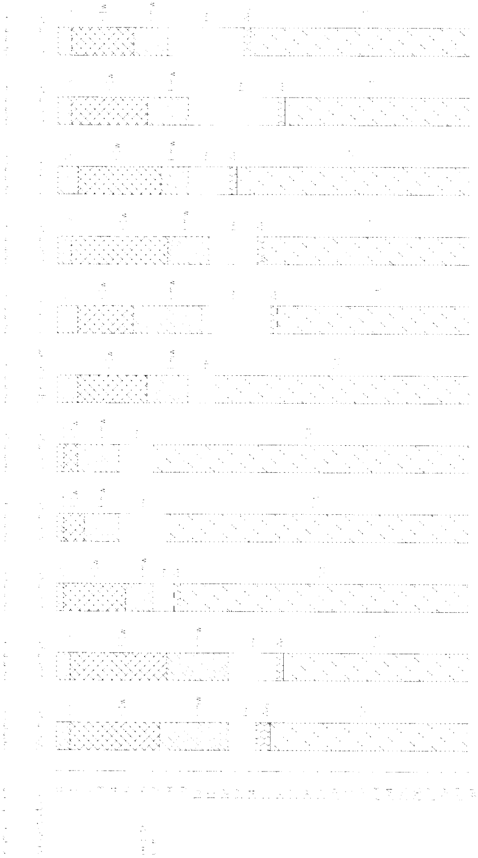

Fig. 4. Humus profile on research plot No 25. Legend: See Green et al. (1993) for explanation of used abbreviated terms.

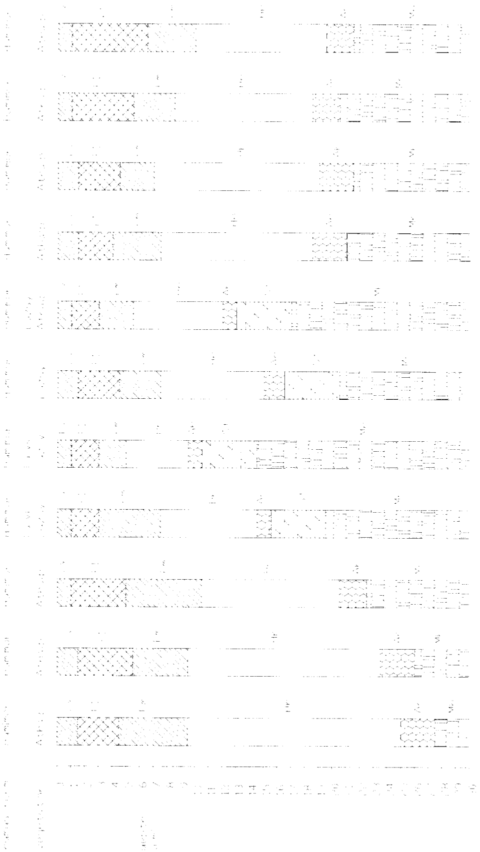

Fig. 5. Humus profile on research plot No 1. Legend: See GREEN et al. (1993) for explanation of used abbreviated terms.

Fig. 6. Humus profile on research plot No 29. Legend: See GREEN et al. (1993) for explanation of used abbreviated terms.