JOURNAL OF FOREST SCIENCE, *52*, 2006 (10): 439–445

Logging and forest decline effects on the surface humus horizons in the Šumava Mts.

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ABSTRACT: Holorganic layers belong among the key ecosystem components of forest soils at higher altitudes. Increased biological activity of the surface humus is very often observed after forest decline and/or forest cut and removal at these sites. The forest removal or tree layer extinction was studied in the flat, water affected terrain: its effects on the soil chemical characteristics and on the soil respiration, ammonification and nitrification activities. The standard methods of analyses were used. The study proved the increased intensity of nitrification and ammonification in stands with decreased ecological as well as environmental function potentials, further decreased concentrations of magnesium. Due to the concentration effects, the concentrations of some macroelements – nitrogen, calcium – increased in these stands (in the humus form layers), as well as the base content and base saturation.

Keywords: Bohemian Forest Mts.; forest soils; humus forms; biological activity; soil chemistry; forest decline

The surface humus component represents an important element of the organic matter dynamics, as well as of the nutrient cycle and energy flow. Its importance increases at higher altitudes. On the contrary, the increased activity of surface soil layers represents one of the potential risks for site sustainability after the tree layer decline or removal. Harmful effects are to be expected especially in more extreme localities, endangered by the intro-skeletal erosion (ISE). The published results (Svoboda, Podrázský 2003, 2005; Vacek, Podrázský 2003; Vacek et al. 2003) indicated degradation effects of the forest cut or decline on the forest soil state in the mountain localities of the Krkonoše as well as Šumava Mts. (Bohemian Forest Mts.) (Podrázský, Karas 2002). The presented article analyses the humus form dynamics in a further locality with the aim to make broader the spectrum of site and technological conditions concerning the forest decline in the Šumava Mts. (Bohemian Forest Mts.). Large areas were put under this unfavourable dynamics by the inappropriate forest ecosystem management (passive approach), lacking the competency.

MATERIAL AND METHODS

The sampling was performed on Oct 7th 2004 on three location variants in comparable site conditions in the Studená hora locality. It is the territory of the Modrava Forest District, where the particular studies are performed. The site conditions are summarized in Table 1. The samples from F, H and Ah horizons were taken in four replications in each locality, representing the vital forest, dead forest as well as the clear-cut (plots 3, 4, 5). The soil analyses were carried out in the Tomáš laboratory (Forestry and Game Management Research Institute, Research Station Opočno).

The forest decline (by bark beetle) and cut on the part of the area took place in the years 1995–1997, the plots representing 10 years since the event. The humus form state was compared with the vital forest part.

The standard pedochemical and pedobiological analytical methods were used:

- soil reaction in water and 1 N KCl solution,
- the adsorption complex characteristics according to Kappen (S – base content, H – hydrolytical

Supported by the Ministry of Agriculture of the Czech Republic, Project No. QG50105, and the Ministry of Education, Youth and Sports of the Czech Republic, Project No. 2B06012.

Table 1. Characteristics of permanent research plots in the Studená hora locality (state 1999)

Plot	Stand	Altitude (m a.s.l.)	Slope	Forest type	Age	Moss cover (%)	Vegetation cover (%)	Note
3	68B	1,120	flat	8R1	120	70	95	wet – peaty, living, vital
4	68B	1,120	flat 1°	8O1	130	20	95	declined
5	68B	1,120	flat	8S1	0	15	100	dead wood on mounds, clear-cut
6	68B	1,120	flat	8S1	0	15	100	dead wood on mounds, clear-cut

activity, T – cation exchange capacity, V – base saturation),
- plant available nutrients in a 1% citric acid solution (P – Spekol, K – flame photometry, others AAS),
- plant available nutrients by Mehlich III,
- total nutrient content after mineralization by a mixture of sulphuric acid and selenium,
- standard methods of determination of basal soil respiration and potential one, nitrification and ammonification (Podrázský et al. 2002; Podrázský, Svoboda 2002; Svoboda, Podrázský 2005).

RESULTS

The adsorption complex characteristics are documented in Table 2. After 10 years of the clear-cut prevailing conditions the soil pH was higher on the clear-cut as well as in the declined (dead) stand, higher values were registered on the clear-cut. The changes were visible in the holorganic layers, not in the mineral horizon.

The exchangeable base content was higher also prevailingly on the clear-cut, a marked difference was observed between vital and dead stand. On the contrary, the hydrolytical activity was the highest in the living stand part (holorganic layers). In the mineral substrate the H-values were very similar. The cation exchange capacity showed a similar trend in the F-horizon, the increased values were documented in the mineral horizon of the clear-cut. These trends resulted in the higher values of the base saturation on the clear-cut in the whole profile studied as well as in the declined stand in contrast with the living forest stand, i.e. vital forest ecosystem, in the holorganic horizons. A certain decrease in the characteristics of exchangeable acidity was observed in the declined forest, on the contrary these characteristics were highest on the clear-cut. This aspect needs a more detailed study.

The characteristics of the surface humus revealed trends typical of the situation of the removal of soil protection effects of forest stands. At the given site, the changes were more marked on the clear-cut subplot. This tendency represents a certain difference from more extreme sites (Svoboda, Podrázský 2003, 2005). In these cases, the sites of declined and cut forest were much closer to the other, opposite to the vital forest stand. On the plots described in this article, the longer time since the forest decline (ca. 10 years) and high necromass accumulation in the past affect the slightly different results, as well as the microsite differences play the role. Although the plots are in one homogeneous series, longer absence of vital stands was reflected by a slightly different typological description of particular plots.

The next table, Table 3, documents the contents of total humus, nitrogen, as well as plant available nutrients in the citrate solution. The humus content was similar on all plots as for holorganic layers, it was

Table 2. Soil reaction and state of soil adsorption complex on particular plots of the Studená hora locality

Plot	Horizon	pH H_2O	pH KCl	S	H	T	V (%)	Aci_{ex}	H_{ex}	Al_{ex}
				(meqv/100 g)				(meqv/kg)		
Vital	F	3.1	2.2	12.6	71.7	84.3	15.0	85.0	41.7	43.3
	H	3.0	2.1	9.2	85.2	94.4	9.7	128.8	28.6	100.2
	A	3.5	3.1	1.6	13.9	15.5	10.4	61.2	0.6	60.7
Declined	F	3.2	2.3	15.6	65.5	81.2	19.2	71.9	29.2	42.7
	H	3.2	2.4	13.9	61.4	75.3	18.4	82.5	10.6	71.9
	A	3.5	2.8	0.9	12.2	13.0	6.7	44.9	1.3	43.6
Clear-cut	F	3.5	3.0	19.4	65.5	84.9	22.9	135.5	2.6	132.9
	H	3.7	3.0	14.3	60.1	74.4	19.2	147.5	2.0	145.6
	A	3.8	3.4	4.7	15.6	20.3	23.0	64.0	0.7	63.2

Table 3. Total humus, nitrogen and plant available nutrients (1% citric acid solution) on particular plots of the Studená hora locality

Plot	Horizon	Humus SK (%)	N Kj (%)	P_2O_5	K_2O	CaO	MgO	Fe_2O_3
				(mg/kg)				
Living	F	63.1	1.91	184	303	840	216	95
	H	59.3	1.82	145	263	413	171	213
	A	9.4	0.24	225	48	93	31	2,603
Declined	F	64.9	1.91	171	215	1,720	289	128
	H	53.2	1.78	203	164	987	181	371
	A	7.8	0.27	145	50	147	35	1,746
Clear-cut	F	59.5	2.01	307	335	2,000	248	660
	H	61.6	2.26	324	215	747	133	2,199
	A	12.1	0.44	260	44	207	44	3,086

the highest on the clear-cut in the mineral horizon. Total nitrogen was also the highest there, on the other hand, the situation was similar in the declined and vital forest stand.

The plant available phosphorus and iron contents were also increasing on the clear-cut, which corresponds with the total exchangeable acidity values. The plant available P content was lowered in the dead stand compared to the vital one. The plant available K content was similar on all plots, more lowered in the declined forest. The Ca and Mg contents increased on the clear-cut more, indicating the relative enrichment of surface substrates.

The plant available nutrient contents according to the Mehlich III method and the total nutrient contents are shown in Table 4. The plant available phosphorus content was increased in the declined stand, being comparable on other sites. In the total form, it was the highest on the clear-cut. Especially this site type, i.e. the clear-cut, shows higher P-contents of forms and the relative enrichment by this nutrient is indicated there.

The plant available potassium content was decreasing in the dead stand in the holorganic horizons compared to the clear-cut (corresponding to the citric acid solution analysis), it increased slightly in the mineral horizons. This may indicate leaching from upper to lower mineral layers. The K-content increase in the lower holorganic horizon supports this assumption. The increase of the available calcium content was observed, more in the declined stand, less on the clear-cut, the same was determined for the total Ca-form. Decline or cut of the stand resulted in the enrichment as for this macroelement.

On the contrary, the plant available magnesium content showed a tendency of a moderate increase in the dead stand, on the clear-cut the decrease was more marked compared to the citrate solution analysis. The decrease was very marked in the total Mg-form, especially on the clear-cut.

It can be concluded that the decline and/or cut of the stand resulted in the relative enrichment of the uppermost soil layers with nitrogen, less with phosphorus and calcium. On the contrary, the leach-

Table 4. Plant available (Mehlich III) and total nutrient content on particular plots of the Studená hora locality

Plot	Horizon	P	K	Ca	Mg	N	P	K	Ca	Mg
		(mg/kg)				(%)				
Living	F	28	594	1,720	198	1.93	0.07	0.10	0.020	0.032
	H	20	392	1,106	144	1.73	0.06	0.14	0.004	0.020
	A	1	99	370	26					
Declined	F	32	398	2,734	226	1.95	0.06	0.08	0.040	0.036
	H	32	340	1,570	142	1.67	0.08	0.22	0.012	0.004
	A	14	111	387	28					
Clear-cut	F	34	418	2,044	136	2.05	0.09	0.10	0.060	0.004
	H	18	346	1,300	100	2.07	0.15	0.18	0.004	0.008
	A	2	114	488	34					

Table 5. Respiration activity on particular plots of the Studená hora locality

Plot	Horizon	Moisture (%)	Basal respiration (mg CO_2/100 g DM/24 h)					Potential respiration
			1. day	2. day	3. day	4. day	5. day	
Vital	F	65.0	188.2 a	164.8 a	168.0 a	146.6 a	120.8 a	443.8 a
	H	69.0	104.2 a	90.8 a	92.2 a	90.1 a	71.0 a	251.2
	A	34.1	23.1	5.4 a	5.4 a	8.0 a	3.6 a	48.1 a
Declined	F	79.8	118.7 b	95.8 b	93.7 b	87.2 b	56.6 b	270.1 b
	H	75.1	53.1 b	43.3 b	41.5 b	50.4 b	33.6 b	260.0
	A	35.2	32.2	21.8 b	16.6 b	11.6 ab	9.5 b	35.3 a
Clear-cut	F	75.9	175.4 a	146.2 a	140.7 a	125.2 a	109.6 b	460.5 a
	H	75.1	102.4 a	76.8 a	76.0 c	59.2 b	60.9 a	278.0
	A	44.7	33.1	23.9 b	24.3 c	21.5 b	11.2 b	144.0

ing of potassium and even more of magnesium was documented.

Table 5 contains the results of the analysis of basal as well as potential respiration of soil substrates from different types of studied localities. As for the soil moisture in the time of sampling, it was slightly lower in the holorganic layers of the living stand and moderately higher in the mineral substrate of the clear-cut. The differences were not large.

The basal respiration was the statistically significantly highest in the holorganic horizons of the living stand, lower values were documented for the clear-cut and the lowest for the declined forest. In the course of the experiment (5 days), the respiration was decreasing in all variants. The trend of decrease was also observed in the mineral substrate, in this case the values from the living stand were the significantly lowest. The differences between the clear-cut and the declined stand were not significant, they were slightly lower in the dead forest. A similar trend of differences between the living and dead stand was documented also for the potential soil respiration, the non-significant increase was observed on the clear-cut compared to the control and living stand.

The results document the most intensive biological respiration activity in the holorganic horizons of the living stand, the removal of tree layer and development of grass vegetation result in the increase of the potential respiration activity above this level.

The substrates from the clear-cut showed the highest ammonia ion content in the time of sampling. The holorganic layers in the dead stand contained slightly lower contents of this ion, on the contrary, the mineral layer had the higher one compared to the living stand. The substrate incubation lead to the significant decrease in the holorganic layers in the declined stand and to the increase on the clear-cut, the increase was documented in both cases in the mineral horizon.

The dynamics of the nitrate N-form is considered as critical after the forest decline from the ecological point of view. Considerably (order size) higher

Table 6. Nitrogen dynamics characteristics on particular plots of the Studená hora locality

Plot	Horizon	Ammonia ion content (mg/kg)			Nitrate ion content (mg/kg)		
		original DM	DM	fresh	original DM	DM	fresh
Vital	F	202.6	606.8 a	212.4 a	17.4	16.2 a	5.6 a
	H	93.2	360.5 a	111.8 a	5.2	8.2 a	2.6 a
	A	94.4	144.3 a	95.1	34.1	26.0 a	17.1 a
Declined	F	173.3	445.9 b	90.1 b	350.5	283.5 b	57.3 b
	H	78.2	283.4 b	70.6 b	148.6	93.2 b	23.2 b
	A	110.8	154.6 a	100.2	17.1	8.9 b	5.8 b
Clear-cut	F	253.1	560.5 c	135.1 c	210.8	29.6 a	7.1 a
	H	169.2	426.8 c	106.3 a	119.3	86.6 b	21.6 b
	A	156.6	185.0 b	102.3	19.5	16.2 c	9.0 c

DM – dry matter, fresh – calculated per fresh matter mass

nitrate contents of nitrates were documented in freshly sampled substrates in our case, especially in the declined forest and holorganic horizons (Table 6). On the contrary, the nitrate content was slightly higher in the mineral horizon of the living stand. The sample incubation led to the significant increase of the nitrification activity in holorganic horizon in the dead stand, lower also on the clear-cut. The opposite was documented for the mineral substrate, both calculated per dry matter of fresh material.

DISCUSSION AND CONCLUSIONS

The studied stands are located in less extreme conditions compared to other studied plots, especially those in the Plechý altitudinal transect and further in the Smrčina massif (Podrázský et al. 2002; Podrázský, Svoboda 2002; Svoboda, Podrázský 2003, 2005). This is connected with less deterministic conclusions in contrast to those cited studies – nevertheless, the changes of humus form dynamics were observed also in the presented case.

The forest stand decline increased considerably the nitrification intensity. This aspect represents the main potential of danger for forest soils in the case of large-area forest declines. On the clear-cut, the nitrification intensity also increased, but not to such an extent. The nitrate content and nitrification dynamics were opposite in the mineral soil layer. Non-natural input or formation of nitrates can result in the progressive acidification of the soil with considerable losses of bases (Podrázský, Ulbrichová 2003).

The increased content of nitrates in the dead/declined stand was accompanied by the lower content of ammonia ions. The content of both forms of mineral nitrogen was higher on the clear-cut and the N-dynamics was more prominent. In the case of forest function decline, the danger of nitrogen leaching increases, especially in the nitrate form. This was already documented, although to the sub-critical extent (Pavlásek et al. 2005).

The basal respiration activity values were the highest in the living, vital stand while they were the lowest in the dead one – at least in the holorganic layers.

The values of the respiration activity were the highest in the living, vital stand, being the lowest in the declined one – in the holorganic layers. The removal/decline of the stands resulted in increased respiration activity in the uppermost mineral layers, higher in the case of clear-cut.

The documented dynamics of the pedo-biological characteristics of the soil substrates affected also the dynamics of macroelements. The concentrations of total nitrogen increased in the whole studied profile on the clear-cut, the values being similar on other sites. The contents of total Mg decreased considerably (more on the clear-cut) whereas the increase of the total P-content was observed. Outside the vital stand, the leaching of calcium and potassium in deeper horizons and outside the rhizosphere is highly probable.

Outside the vital stand, the pH of substrates is also increasing and the soil adsorption complex is improved, at least relatively. The changes are visible especially on the clear-cut, less prominent in the declined stand.

The soil dynamics is probably closer between vital and declined stand in this locality, compared to the clear-cut. This trend in the studied locality differs to a greater extent from other, more extreme sites (Podrázský et al. 2002; Podrázský, Svoboda 2002; Svoboda, Podrázský 2005). It is a consequence of less extreme localities and lower exposure to unfavourable abiotic factors. Also the higher effects of the groundwater can play a role as well as a longer time period since the forest stand decline/cut. In any case, it is necessary to switch from one-time studies to more continuous research to reveal dynamics in the season during longer periods.

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Received for publication April 27, 2006
Accepted after corrections May 19, 2006

Účinek těžby a hynutí lesa na horizonty nadložního humusu na Šumavě

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ABSTRAKT: Holorganické vrstvy jsou jednou z klíčových složek lesních ekosystémů vyšších poloh. Na exponovaných lokalitách byla po odumírání lesních porostů nebo při jejich vytěžení často dokládána zvýšená biologická aktivita substrátů nadložního humusu. V plochém, vodou ovlivněném terénu byl sledován vliv vytěžení a odstranění lesa a vliv jeho odumírání na stav půdního chemismu a na dynamiku půdní respirace, amonizace a nitrifikace. Byly použity standardní pedochemické a pedobiologické metody. Šetření prokázala především zvýšenou úroveň nitrifikace a amonizace v porostech se sníženou environmentální a ekologickou funkčností, dále pak značné ztráty hořčíku. Díky efektu koncentrace došlo v humusových formách naopak ke zvýšení obsahu dusíku a dalších makroelementů a ke zvýšení hodnot charakteristik půdního sorpčního komplexu.

Klíčová slova: Šumava; lesní půdy; humusové formy; biologická aktivita; půdní chemismus; odumírání lesa

Složka nadložního humusu představuje důležitý prvek dynamiky organické hmoty a živin i toku energie v lesních ekosystémech. Její význam roste ve vyšších nadmořských výškách. Zvýšená aktivita povrchových vrstev lesních půd pak představuje jedno z potenciálních nebezpečí pro setrvalost vývoje stanovišť po narušení stromové složky lesních ekosystémů. Příspěvek představuje rozbor stavu na další lokalitě s cílem rozšířit spektrum sledování a základnu poznatků o dynamice lesních půd v oblasti postižené hynutím lesa v důsledku nedostatečně a nekompetentně kontrolované expanze kůrovců na Šumavě. Odběr vzorků humusových forem se uskutečnil 7. 10. 2004 na třech typech lokalit v podobných stanovištních podmínkách na lokalitě Studená hora. Jedná se o oblast LS Modrava, především okolí Březníku, plochy mají velikost 50 × 50 m. Stanovištní charakteristiky shrnuje tab. 1. Vzorky byly odebírány ve čtyřech opakováních z horizontů F, H a A na ploše 3, 4 a 5. Analýzy byly prováděny v laboratoři firmy Tomáš (Výzkumný ústav lesního hospodářství a myslivosti, Výzkumná stanice Opočno). Výsledky pak sumarizují tab. 2 až 6.

Sledované porosty leží v méně extrémních podmínkách ve srovnání s jinými sledovanými lokalitami – především na výškovém transektu Plechý a dále v masivu Smrčiny (viz literatura). Z toho zřejmě především plynou i méně jednoznačné závěry ve srovnání s jinými studiemi. Nicméně změny v dynamice humusových forem byly patrné i v tomto případě.

Odumření porostů zvýšilo výrazně úroveň nitrifikace. Tento aspekt představuje především hlavní potenciální ohrožení stavu lesních půd v případě

rozpadu lesních porostů. Na holině byla úroveň nitrifikace rovněž zvýšena, ale ne tak výrazným způsobem. V minerální zemině byl trend opačný a obsah nitrátů nižší.

Zvýšený obsah nitrátů v odumřelém porostu byl provázen nižším obsahem amonného iontu. Na holině byl vyšší obsah obou forem minerálního dusíku a jeho dynamika tak byla výrazně vyšší. V případech obou porostů s odstraněnou funkční porostní složkou tak výrazně roste nebezpečí vyplavování dusíku především v nitrátové formě.

Hodnoty respirační aktivity byly nejvyšší v porostu živém, v odumřelém byly naopak nejnižší – v holorganických vrstvách. Odstranění vlivu porostů pak mělo za následek naopak zvýšení respirační aktivity nejsvrchnější minerální vrstvy, větší v případě holiny.

Uvedená dynamika pedobiologických charakteristik měla dopad i na obsahy makroelementů. V celém sledovaném profilu vzrostly koncentrace celkového dusíku na holině, u zbylých porostů byly hodnoty velice podobné. Výrazně, především na holině, poklesl obsah celkového hořčíku, obsah celkového fosforu zde naopak vzrostl. Mimo živý porost pravděpodobně dochází k posunu celkového vápníku a draslíku do spodnějších horizontů.

Mimo živý porost roste půdní reakce a zlepšuje se stav půdního sorpčního komplexu. Změny jsou patrné především na holině, méně výrazné jsou v rozpadlém porostu.

Půdní dynamika je patrně bližší mezi živým a odumřelým porostem než mezi odumřelým porostem a holinou. Stav na studované lokalitě se tak dosti odlišuje od jiných, více exponovaných stanovišť. Je to důsledek jednak menší extremity stanovišť, jednak jejich menší expozice – v našem případě jsou sledované lokality v plochém terénu s patrným vlivem spodní vody. Rovněž dlouhá doba od odstranění vlivu porostu (asi 10 let) může mít důležitou úlohu. V každém případě je v budoucnu třeba přejít od jednorázových šetření k trvalejšímu sledování, podstatně náročnějšímu metodicky, finančně i pracovně.

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