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PROCESS OF SELF-REGENERATION OF THE POST-HARVESTED AREAS OF PEATBOGS IN THE ORAWA - NOWY TARG BASIN

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ABSTRACT

The presented paper is an edited version of the part of Ph.D. thesis of the same title and by the same author. The main aim of the research was to assess the state of peat formation process on post-harvested fields of the selected raised bogs in the Orawa – Nowy Targ Basin on the basis of the acrotelm layer self-regeneration. The results revealed that the peat formation process takes place on six from among eight investigated bogs and statistical analysis of the percentage coverage by three plant groups proved that there are significant differences between them. The attempt to determine the rate of organic mass increase on post-mined areas by means of dendrological method was undertaken. Survey results suggest that the rate of organic mass accumulation on the investigated areas is high and depends on local conditions.

Key words: acrotelm, regeneration, organic mass accumulation, Orawa - Nowy Targ Basin

INTRODUCTION

For about 150 years peatlands in the Orawa-Nowy Targ Basin have been a subject to larger and larger degradation in consequence of peat winning. Nowadays, hardly any of them has saved its primeval character.

After ending of peat extraction post-harvested areas are usually abandoned and left to "the nature". However, especially in case of milled peat, range of devastation causes that the process of natural regeneration into a functioning peatbog ecosystem doesn't even start after dozens of years.

The spontaneous colonisation of post-mined areas by vegetation is a long-lasting process determined by many factors of different nature and that is why it hasn't been thoroughly recognised yet. However, it is known that the key factor in regeneration of raised bogs is the acrotelm layer, the main components of which are sphagnum mosses. With its rather little depth reaching 0.5 m an acrotelm shows specific properties and by regulation of the hydrological processes it controls the growth mechanism of the peatbog. Therefore it can be stated that the presence of *Sphagnum* spp. on raised bogs and in their surroundings is a basic factor that decides of the dynamics of peat formation process. The habitat requirements of sphagnum mosses (susceptibility for water deficit) cause that in many cases plant succession takes undesirable direction.

In recent years the increase of interest of different circles (scientific, ecological etc.) in peatlands renaturalization and protection can be observed. In many countries (Canada, the Netherlands, Germany, Finland, UK etc.) the attempts to initiate the peat formation process on post-harvested areas are undertaken. Field experiments are carried out to work out the peatlands reclamation methods that would enable to create the optimum conditions for establishment of *Sphagnum* dominated plant communities.

From the point of view of nature conservation, manipulating peatlands renaturalization process stands in conflict with their "naturalness" that makes them so unique [9]. Therefore, the only possibility to protect this complex ecosystems arising for thousands of years is to stop destroying them.

STUDY AREA

In the Orawa – Nowy Targ Basin 26 peatlands are located which occupy total area of 23.47 km^2. They spread between the Orawa water reservoir and peatbog nature reserve Bór na Czerwonem near Nowy Targ. There are 14 raised bogs there, 10 fens and 2 transition bogs. Raised bogs occupy the area of 15.95 km^2, what represents 68.4% of the total area of all peatbogs. In some parts of fens and raised bogs, especially on post-mining areas transitional character can be observed [12].

The investigations were carried out on eight selected sites, the short characteristic of which is presented in table 1.

Table 1. Characteristic of the selected peatbogs and post-harvested areas

Name of peatbog	Area [ha]		Peatbog type	Peat extraction		Thickness of remaining peat layer [m]	Other notices
	total	dome		hand cutting	industrial scale		
Puścizna Rękowiańska (Baligówka)	204.43	151.81	raised	Formerly along almost the whole edge and on the dome; at present mainly in the northern part	In the 50s peat cutting in the southern part of the dome (about 35 ha)	2.0 and more; in places to the mineral substratum	-
Puścizna Wielka	449.36	-	raised	Formerly along almost the whole edge and on the dome; at present occasionally	Extraction from the 60s at first by block-cutting, but at present by milling method (about 12 ha)	0.5 and more; in places to the mineral substratum	-
Puścizna Mała	81.19	-	raised	Formerly along almost the whole edge and on the dome; at present mainly in the north-western part	-	0.5-1.0 and more	Sphagnum mosses harvesting
Bór za Lasem – Kaczmarka	47.59 11.41 59.00	-	raised	Formerly along almost the whole edge and on the dome; at present mainly in the north-eastern part	Extraction in the years 1955 – 1993/96; in the northern part by block-cutting (16 ha) and then in the southern part by milling method (24 ha)	0.5-1.0 and more; in places to the mineral substratum	Rail-track divides post-mined field to northern and southern part
Pustać Chyżne C	73.01	20.62	raised	Formerly along almost the whole edge and on the dome; at present occasionally	-	1.0 and more; in places to the mineral substratum	-
Urbarski Las	19.62	-	raised	Formerly along almost the whole edge (mainly in western part) and on the dome; at present occasionally	-	0.5-1.20 and more; in places to the mineral substratum	-
Bór na Czerwonem	57.77	37.08	raised	Formerly along almost the whole edge and on the dome, mainly in the northern and north-eastern part (landing field today);	-	0.5-2.0 and more; in places to the mineral substratum	Nature reserve since 1925 on the area of 49.7 ha; secondary paludification and lagg extending
Otrębowskie Brzegi	34.42	-	fen, transition, raised	Formerly along almost the whole edge and on the dome; mainly in the western part; at present occasionally	-	0.5 and more	-

SCOPE AND METHODS OF INVESTIGATION

The scope of the investigation was to estimate the present state of peat forming process on post-harvested fields of the selected raised bogs in the Orawa – Nowy Targ Basin by the evaluation of the degree of the acrotelm layer self-regeneration. To achieve this aim the method described by Rochefort et al. [19] was employed. The establishment of a vegetated cover was assessed by evaluating the percentage coverage of three plant groups: 1. sphagnum mosses, 2. other bryophytes and 3. vascular plants. A sampling field frame (75 x 75 cm) was used to that purpose and the percent cover by three groups of plants in 4 corner quadrates of 25 x 25 cm was evaluated with precision of 5%. The average value of cover per stratum for all quadrates was calculated, therefore the total percentage coverage by all strata may exceed 100% [14]. To assess continuity of the acrotelm layer 30 measurement points were located every 5 m along transect lines (270 measurement points in total). Moreover, at each point the depth of the acrotelm was measured and then the average value was calculated.

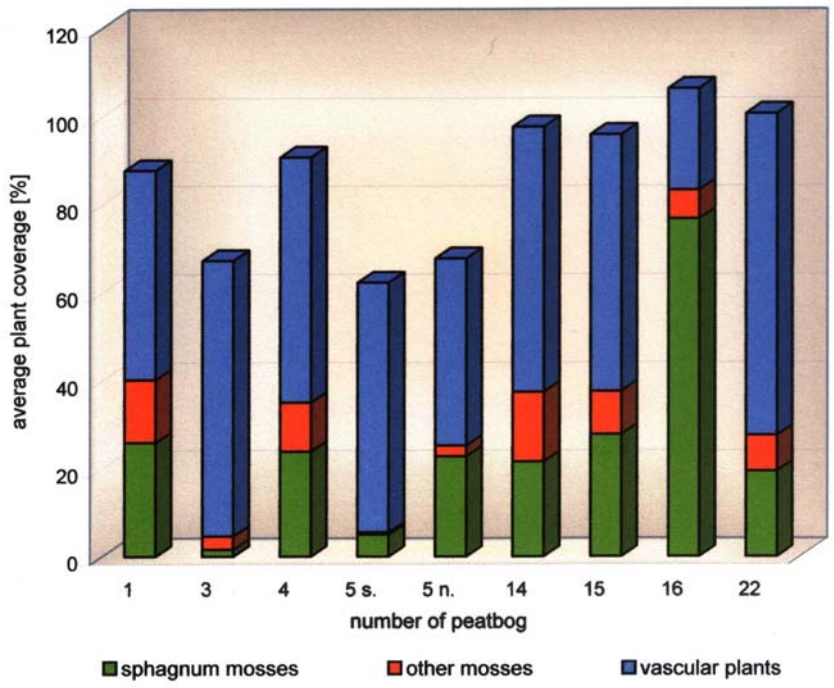
Field investigation results were analysed statistically. To determine differences in coverage by three plant groups between surveyed areas one way variance analysis by the Fisher-Snedecor test was employed and LSD values were calculated [21].

Furthermore, the attempt to determine the rate of organic mass increase on post-mined areas by means of dendrological method was undertaken. At the time of a tree seed germination peat level is at the base of its root neck. Simultaneously with the tree growth the organic mass depth increases and tree tank immerses in it. The annual linear rate of organic mass increase was determined by dividing the depth of organic mass layer (measured from a tree root neck) by the number of annual tree-rings [10, 15, 2]. The age of trees (Scotch pine *Pinus sylvestris*) was defined for 20 specimens, on 5 objects. Wood samples were taken by means of the borer at the base of tree root neck and the number of annual tree-rings was counted using magnifying glass [4].

RESULTS AND DISCUSSION

The lowest average plant coverage was found on post-mined fields of the Bór za Lasem – Kaczmarka and the Puścizna Wielka bogs where peat mass was extracted by milling method, while the highest one in case of the nature reserve Bór na Czerwonem (Fig. 1).

Fig. 1. Average plant coverage on post-harvested areas of the investigated peatbogs



Peatbog number: 1 – Puścizna Rękowiańska, 3 – Puścizna Wielka, 4 – Puścizna Mała, 5 s. – Bór za Lasem - Kaczmarka (southern part), 5 n. – Bór za Lasem- Kaczmarka (northern part), 14 – Pustać Chyżne C, 15 – Urbarski Las, 16 – Bór na Czerwonem, 22 – Otrębowskie Brzegi

Many scientists stress that the conditions for spontaneous colonisation of mire plant species, especially establishment of *Sphagnum* spp. on bare peat substratum after peat milling activities ending are very likely to provide an inhospitable environment [23, 18, 5, 11, 17]. The state of re-colonisation of the Bór za Lasem – Kaczmarka and the Puścizna Wielka confirms those opinions thoroughly.

In the southern part of the post-mined field of the Bór za Lasem – Kaczmarka plant concentrations can be found locally rather and the vegetation is characteristic of drier conditions. The species composition is dominated by common heather (*Calluna vulgaris*) and cotton-grass (*Eriophorum vaginatum*) along with birch invasion (*Betula pendula, B. pubescens*) [Phot. 1, 2]. Sphagnum mosses occur occasionally and on areas of open water exclusively (e.g. blocked ditches, hollows) [Phot. 3]. The same plant succession direction can be observed in case of the Puścizna Rękowiańska but with even lower percentage of sphagna. Such a course of colonisation process was reported on many other sites [e.g. 16, 23, 5, 20].

Phot. 1. View on the post harvested area of the Bór za Lasem – Kaczmarka (southern part)

Phot. 2. Birch invasion on post-harvested area of the Bór za Lasem – Kaczmarka

Phot. 3. *Sphagnum cuspidatum* development in a drain ditch filled with water

The best state of renaturalization was observed on the post-mined areas of the Bór na Czerwonem peatbog where the lagg is extending horizontally due to intense waterlogging. Sphagnum mosses dominate decidedly, especially *Sphagnum cuspidatum* with a modest presence of vascular plants.

Statistical analysis of the percentage coverage data carried out for sphagnum moss, other bryophytes and vascular plants proved that there are significant differences between investigated areas. For the three plant groups the intervals were determined including peatbogs of the average percentage coverage within the limits designated by the LSD values (Table 2).

The lowest variation of the investigated feature was stated for sphagnum mosses (3 groups) while the highest one for other mosses (6 group) and vascular plants (5 groups).

In case of other bryophytes and vascular plants the number of intervals can be explained by various habitat requirements of individual plant species of both groups. Besides, the factor or group of factors that influence on the vegetation cover development and establishment can be different for each object.

Generally, it is easier to interpret the ground cover by sphagnum mosses because of its narrow ecological tolerance to water conditions. On post-harvested fields other bryophytes and vascular plants colonise peat surface of different moisture degree, including overdried areas that are inaccessible for sphagnum mosses.

Table 2. Average plant coverage of the investigated areas by the three plant groups and calculated LSD values (Tukey test; $\alpha = 0.05$)

Name of peatbog (No.)	Coverage [%] Average values	$LSD_{\alpha=0.05}$
Sphagnum mosses		
Puścizna Wielka (No. 3)	1.6	25.7
Bór za Lasem – Kaczmarka s. (No. 5)	5.0	
Otrębowskie Brzegi (No. 22)	19.5	
Pustać Chyżne C (No. 14)	21.6	
Bór za Lasem – Kaczmarka n. (No. 5)	22.8	
Puścizna Mała (No. 4)	23.9	
Puścizna Rękowiańska (No. 1)	26.0	
Urbarski Las (No. 15)	27.8	
Bór na Czerwonem (No. 16)	76.7	
Other mosses		
Bór za Lasem – Kaczmarka s. (No. 5)	0.5	7.9
Bór za Lasem – Kaczmarka n. (No. 5)	2.5	
Puścizna Wielka (No. 3)	3.0	
Bór na Czerwonem (No. 16)	6.5	
Otrębowskie Brzegi (No. 22)	8.1	
Urbarski Las (No. 15)	9.8	
Puścizna Mała (No. 4)	11.2	
Puścizna Rękowiańska (No. 1)	14.3	
Pustać Chyżne C (No. 14)	15.9	
Vascular plants		
Bór na Czerwonem (No. 16)	23.1	24.7
Bór za Lasem – Kaczmarka n. (No. 5)	42.5	
Puścizna Rękowiańska (No. 1)	47.5	
Puścizna Mała (No. 4)	55.7	
Bór za Lasem – Kaczmarka s. (No. 5)	56.8	
Urbarski Las (No. 15)	58.3	
Pustać Chyżne C (No. 14)	60.2	
Puścizna Wielka (No. 3)	62.7	
Otrębowskie Brzegi (No. 22)	73.0	

Analysing the ground cover by sphagnum mosses some features can be distinguished that are common for all the investigated areas classified to the same interval. The first of them includes 2 peatbogs: the Puścizna Rękowiańska and southern part of the Bór za Lasem – Kaczmarka. Both of them were exploited by milling method. Post-mined fields together with the adjacent area have been drained by systematic network of ditches and some of them still work. The water table level dropped to 0.60 m in the summer. The acrotelm layer has not developed in any case but sphagnum moss clusters can be found in local depressions filled with water.

Lack of the acrotelm layer in conjunction with low water table level on the investigated post-harvested areas confirms the opinion of many scientists [e.g. 1, 8, 22, 23, 6, 7] who stress that the essential condition for *Sphagnum* re-growth is to maintain stable water table close to the surface (not lower then 0.10 m) and also creation of an areas of open water to limit water level fluctuations and avoid desiccation during dry periods.

The second interval embraces 5 objects from which local people (private owners) exploited peat mass by hand-cutting (the Otrębowskie Brzegi, the Pustać Chyżne C, the Puścizna Mała, the Puścizna Rękowańska so-called Baligówka, the Urbarskie Las) and one object (northern part of the Bór za Lasem – Kaczmarka) exploited on the industrial scale in the past. After peat mining activities ending hydrological conditions on that objects improved. Most of old drainage ditches are presently silted and overgrown. The lowest water table level (0.60 m) was stated in the northern part of the Bór za Lasem – Kaczmarka where no acrotelm layer has formed but sphagnum moss clusters occur in places, whereas for other objects water table level in most cases hasn't dropped below 0.40 m during the dry period. On post-mined fields of that peatbogs the peat formation process takes place. The average thickness of the acrotelm layer ranges from 0.143 m (the Otrębowskie Brzegi) to 0.167 m (the Urbarskie Las).

The third interval includes only one object, the Bór na Czerwonem, which was exploited by hand-cutting in the past but since 1925 it is protected as the nature reserve. In this case water table even in the summer laid about 0.50 m above the ground and the average thickness of the acrotelm reaches 0.255 m (Table 3).

Table 3. Average thickness of the acrotelm layer and the water table level (September 2001, July 2002) on the investigated areas

Name of peatbog (No.)	Thickness of the acrotelm [m] average values	Water table level [m]
Puścizna Rękowiańska (No. 1)	0.156	0.05-0.45
Puścizna Wielka (No. 3)	0.000	0.05-0.60
Puścizna Mała (No. 4)	0.164	0.00-0.40
Bór za Lasem – Kaczmarka s. (No. 5)	0.000	0.05-0.65
Bór za Lasem – Kaczmarka n. (No. 5)	0.000	0.10-0.60
Pustać Chyżne C (No. 14)	0.153	0.00-0.40
Urbarski Las (No. 15)	0.167	0.00-0.25
Bór na Czerwonem (No. 16)	0.255	+0.50-0.00
Otrębowskie Brzegi (No. 22)	0.143	0.00-0.40

From the point of view of the dynamics of peat formation process an interesting phenomenon is the rate of the organic mass increase on post-mined areas. The attempt to determine it was undertaken on 5 objects. The annual linear increase of the peatbog upper layer was determined in two ways: 1. considering the total depth of the organic layer and 2. considering weakly decomposed plant litter only (degree of decomposition about 10%), without the living moss layer [13]. As the degree of decomposition of the organic matter increases its density rises simultaneously, so that the values obtained can not be compared with the increase of the peat deposit (Table 4).

Table 4. Annual increase of the peatbog upper layer on post-harvested areas

Name of peatbog (No.)	Age of tree [years]	Thickness of the organic layer [mm]			Annual increase of the upper layer [mm·year^{-1}]	Annual increase of the layer of R up to 10% [mm·year^{-1}]
		living moss layer	R up to 10%	total		
Puścizna Rękowiańska (Baligówka) (No. 1)	9	40	18	58	6.44	2.00
	19	90	37	127	6.68	1.95
	24	75	70	145	6.04	2.92
	27	87	35	122	4.52	1.30
Average:					**5.92**	**2.04**
Puścizna Mała (No. 4)	18	59	62	121	6.72	3.44
	23	101	112	213	9.26	4.87
	35	97	222	319	9.11	6.34
	47	128	335	463	9.85	7.13
Average:					**8.73**	**5.44**
Bór za Lasem – Kaczmarka s. (No. 5)	15	54	20	74	4.93	1.33
	21	77	29	106	5.05	1.38
	16	82	19	101	6.31	1.19
	24	100	73	173	7.21	3.04
Average:					**5.87**	**1.73**
Pustać Chyżne C (No. 14)	19	65	30	95	5.00	1.58
	22	110	110	220	10.00	5.00
	27	126	147	273	10.11	5.44
	36	151	251	402	11.17	6.97
Average:					**9.07**	**4.75**
Bór na Czerwonem (No. 16)	14	50	17	67	4.79	1.21
	28	136	39	175	6.25	1.39
	31	124	51	175	5.64	1.64
	38	124	90	214	5.63	2.37
Average:					**5.58**	**1.63**

R – degree of decomposition

Survey results suggest that the rate of organic mass accumulation on the investigated areas is high. In each case it exceeded 5 mm per year and on two objects (the Pustać Chyżne C, the Puścizna Mała) it reached nearly twice that value.

There are hardly any scientific results concerning the rate of the peatbog upper layer increase. In the Orawa-Nowy Targ Basin this kind of survey were carried out on the Bór za Lasem – Kaczmarka peatbog only, using radiometric method [3]. The value obtained was 5 mm per year, so very near to the result achieved by means of the dendrological method.

Preliminary study on employing of the dendrological method to determine the annual increase of the peatbog upper layer revealed a limitation on example of one object. The Bór na Czerwonem showed the lowest annual organic layer increment but at the same time the sphagnum cover developed the best from among all the five objects. That situation can be explained by intense waterlogging of the investigated area that on one hand promotes the sphagnum mosses dynamic development but on the other hand inhibits the trees growth. This means that, because of lack of alive trees on watelogged areas, the rate of the peatbog upper layer increase in that conditions can not be determined by dendrological method.

CONCLUSIONS

1. The peat forming process takes place on post-harvested fields of six from among eight investigated bogs. The best state was observed on the nature reserve Bór na Czerwonem while on the Bór za Lasem – Kaczmarka and the Puścizna Wielka it has not even started yet.
2. Statistical analysis of the percentage coverage by three plant groups proved that there are significant differences between investigated areas. The calculated LSD values showed the lowest variation for sphagnum mosses.
3. The method developed by Rochefort et al. employed for evaluation of the degree of the acrotelm layer self-regeneration proved to be useful for assessing the state of the peat formation process what is important from the practical point of view.
4. The attempt to determine the rate of the peatbog upper layer growth on post-mined areas carried out on example of 5 objects indicated that the rate of the organic mass increase is very high and exceeded 5 mm per year. The differences between objects prove the individual character of the process of the organic mass accumulation that depends on local conditions.

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