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# THE GROWTH DYNAMICS OF THE ACROTELM LAYER OF THE RAISED BOG „BÓR ZA LASEM" IN THE ORAWSKO-NOWOTARSKA BASIN

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## ABSTRACT

The paper presents assessment and results of research on the rate of annual increment of organic matter accumulated in the top, only slightly decomposed acrotelm layer of a raised bog, on the basis of the age of trees which grow there (*Pinus sylvestris*). Additionally, the plant cover was characterised. The research showed that the average annual increment amounts to 4.70 mm. The research object is of outstanding environmental importance with considerable aesthetic and landscape values. It is proposed that the bog should become a protected area in the form of a reserve.

**Key words:** raised bog, acrotelm layer, plant cover, rate of annual increment

## INTRODUCTION

In recent years in Poland, attention has been focused on the multi-function significance of all swamps and marshes, and particularly bogs, in the aspect of biodiversity conservation. The question of treating bogs properly as an important landscape-creating element of large value has been very vividly presented by Tobolski [24]. Using the bogs of the Ziemia Świecka region as an example, the above-mentioned author emphasizes the significance of bogs and their complex impact in the ecological system above the level of an ecosystem.

However, the development of the peat industry in the 20th centry as well as short-sightedness in the management of the country's natural resources have led to the devastation and often to the disappearance of many bogs, marshes and swamps Lipka [8,9,11], Łajczak [16], Zając and Lipka [29].

The Orawa-Nowy Targ Basin is an example of this status quo: peat exploitation still takes place there, including its exploitation by private land owners, being beyond official control. Despite of this fact, the bogs in this region have not lost their beauty yet and they are still unique on the European scale.

In this regard, there is an urgent need for their legal protection and renaturization as well as for the reclamation of the former peat exploitation areas.

The characteristics of the bogs in the Orawa-Nowy Targ Basin, their quantitative and qualitative data and their distribution have recently been presented by Lipka [10], Łajczak [15,16], Lipka et al. [14], Zając [28].
The region in question contains 26 bogs whose total area is 2390 ha Lipka et al. [14]. A large majority of them are bogs with ombrogenic alimentation of the Baltic type with characteristically raised domes. The research area belongs to the best-preserved bogs despite the fact that part of its dome has been destroyed during industrial peat exploitation in the years 1955–1993/96.

This bog was selected for the present research due to its quite well preserved acrotelm layer, which – in the aspect of renaturization – is of large significance. Th presence of the acrotelm layer in a bog of the raised type is decisive about its retention capability and shows that the bog is „alive" because the peat-forming process is going on. Therefore, considering that the acrotelm layer in raised bogs is built mainly of peatmosses (*Sphagnum* sp.), their development on ombrogenic bogs is a factor decisive about the dynamics of the peat-creating process – cf. Zając [28].

The presence of peatmosses (*Sphagnum* sp.) is closely connected with the average level of water surface, which under natural conditions should range from 0.10 to 0.30 m from the bog surface – cf. Beets [2], Joosten [5], Wheeler and Shaw [26]. The basic characteristics of the acrotelm layer are described by Tobolski [23]. The determination methods for the organic matter annual increment in the top layer of the peat deposit are given by Korczagin [6] and Piczugin [20]. They are also presented in detail by Zając [27].

In the Orawa-Nowy Targ Basin, research has recently been conducted concerning the issues discussed in the present paper. Boroń et al. [3] made an attempt to determine the organic matter annual increment in the top layer of the peat deposit in the bog „Bór za Lasem" with the use of the radiometric method on the basis of the plutonium content distribution in the stratigraphic profile. The results showed an increment of 5.0 mm/year. Research conducted by Zając [28] in selected former peat exploitation areas showed that the method proposed by Rochefort et al. [21] may be useful for assessment of the condition of the peat-creating process, which has an important practical aspect. Attempting to determine the organic matter annual increment by means of the dendrological method, the above-mentioned author concluded that the increment ranges from 1.63 to 5.44 mm/year (this research was done with the use of a very small number of trees). The varied figures may be proof of an individual course of the organic matter accumulation process, which is different on each bog.

Similar research, with the use of a large number of trees (mainly *Picea abies*), conducted by Malec [17] on raised bogs in the Western Bieszczady Mts showed that the organic matter increment in the acrotelm layer ranges from 3.9 to 5.55 mm/year.

## DESCRIPTION OF THE EXAMINED BOG

The location of the bog „Bór za Lasem" (Fig. 1) indicates that it is situated within the Black Sea catchment area, close to the European Watershed. The bog's plant cover, geological structure and location in the area define it as an ombrogenic raised bog of the Baltic type with a characteristically elevated dome Lipka [7] (Fig 2). The overall area of the peat deposit with its former exploitation area is 47.6 ha; while the remaining part of the dome, i.e. the one which has not been exploited, and where the present research was conducted, is 18.8 ha.

**Fig.1. The location of the peat bog „Bór za Lasem" in the Orawa-Nowy Targ Basin with the research profile A – B**

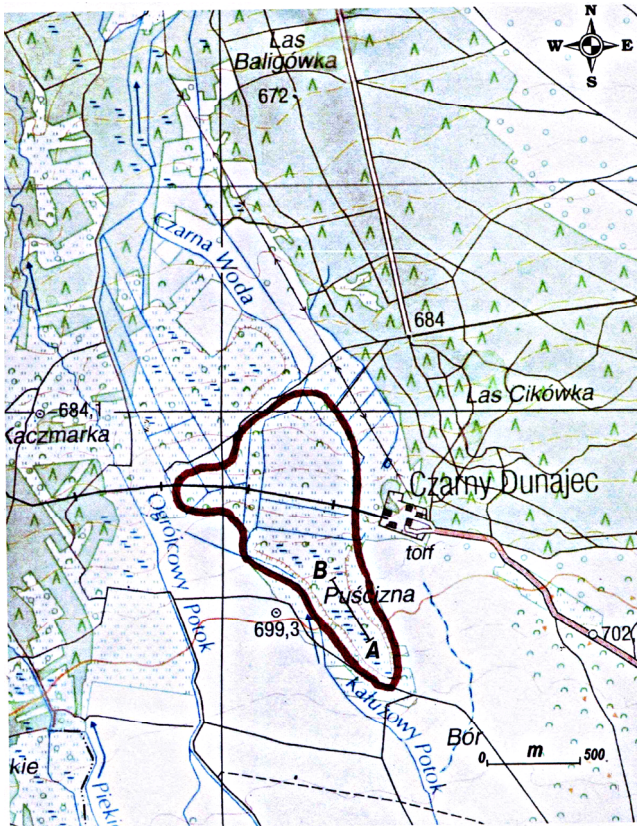
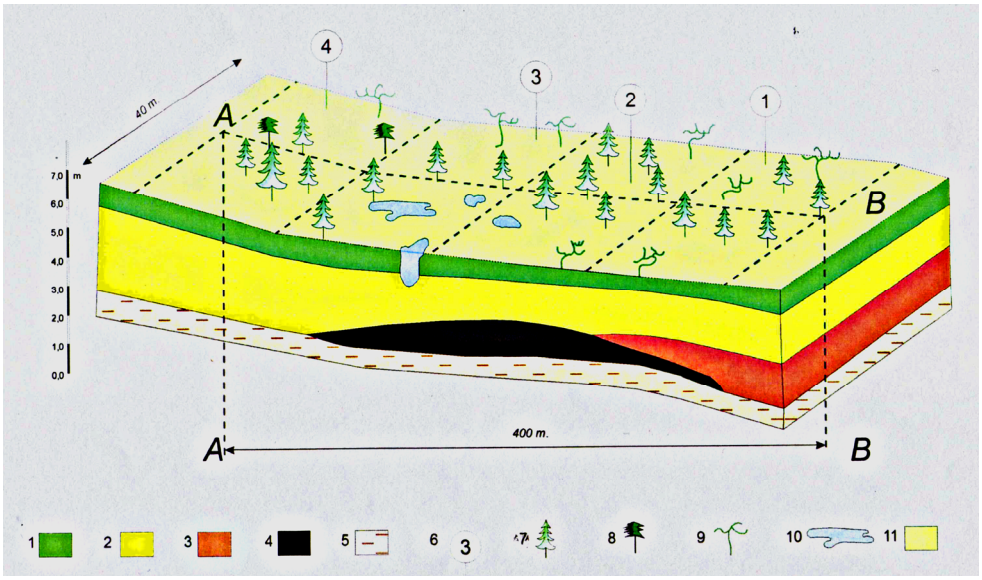


**Fig.2. The characteristic geobotanical research profile A – B on the dome of the peat bog „Bór za Lasem"**




Explanations:

1 – Sphagnum peat (Eusphagneti), 2 – cotton grass-Sphagnum peat (Eriophoro-Sphagneti), 3 – sedge-Sphagnum peat (Sphagno-Cariceti), 4 – peat with a degree of decomposition R>60%, 5 – clay, 6 – sector number, 7 – Pinus sylvestris, 8 – Pinus uliginosum, 9 – Pinus mugo, 10 – peat lakes, 11 – raised bog cover.

The average peat thickness in the dome is 2.73 m whereas the maximum thickness amounts to 3.5 m. The dominant peat type is *Eriophoro – Sphagneti* with the average disintegration degree of 30% and average ash content 2.2% – cf. Lipka [7,10], Lipka and Zając [27].

The peat dome is covered by peatmoss and dwarf shrubs with a large share of trees and bushes of the *Pinus* kind.
The former peat expliotation area in question has the character of a bog of the transition type without the acrotelm layer, typical of raised bogs, which is due to inappropriately performed reclamation.

The statigraphy of the „Bór za Lasem" peat deposit is presented as a characteristic, longitudinal levelling-stratigraphic section, published in Boroń et al. [3] and as the geobotanical research profile A-B, set up by the researchers (Fig. 2).

## RESEARCH AIM, MATERIALS AND METHODS

The main aim of the present research was to assess and determine the annual increment rate of the organic matter accumulated in the surface, poorly condensed acrotelm layer of a raised bog on the basis of the age of the trees which grow there (*Pinus sylvestris*). An additional aim was to characterise the present plant cover and to determine its differentiation according to zones.

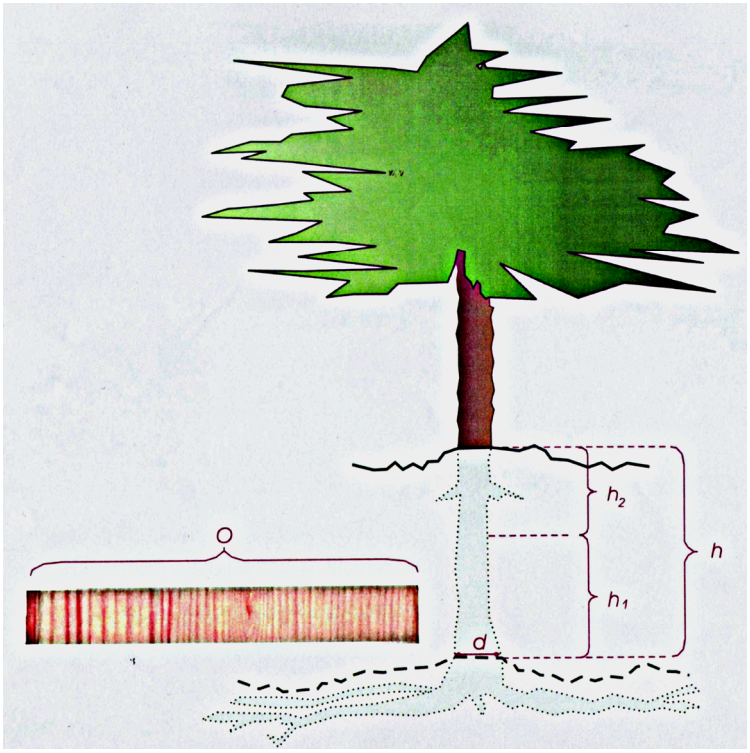
The increment rate of the surface acrotelm layer was assessed by means of the BORGGREVE dendrological method, described by Korczagin [6] and Piczugin [20], and consisting in determination of the annual increment of the surface acrotelm layer on the basis of coniferous trees growing on the bog. The method uses the fact that the seeds of coniferous trees are characterised by overground germination: after the period of rest, the seeds germinate on the bog surface Piczugin [20], Biernat [4], Tomanek [25], Zając [27], Malec [17]. It was assumed that the root neck is a boundary between the trunk and the root system (its location is determined by the level of the soil on which a seed has germinated). The level of the root neck is stable and does not change during the life of a tree. Consequently, the thickness of the acrotelm layer measured above the root neck, divided by tree age, reveals the annual increment of the surface acrotelm layer.

An annual ring of a tree is a layer of xylem cells produced during the vegetation period as a result of the activity of the meristematic cells in the cambium. A visible boundary between latewood from the previous year and earlywood from the next year (observed in coniferous trees and, among deciduous trees, in ring – porous wood) allows for easy calculation of the number of annual rings and measurement of their width.

The number of annual rings in a given place on the tree stem or branch is usually a measure of the age of this tree part. Due to the growth of tree organs at their tops, the elements located closer to the top are younger than the ones located farther. For this reason, determination of the age of a whole tree was based on the annual rings in the root neck zone.
On the dome of the examined bog, along its levelling-stratigraphic profile, a research profile 40 m wide and 400 m long was delimited. On the profile, in 4 sectors (numbered 1–4 from the north southwards), each 100 m long, 5 trees were randomly selected out of the adopted thickness classes: < 6 cm, 6–8 cm, 9–10 cm, 11–12 cm, 13–14 cm.

For each tree, thickness was measured at the breast height (1.3 m) by means of a diameter meter and height by means of the SUUNTO height meter. After uncovering the root neck of each tree, measurements were taken of: $h_1$-thickness of the organic layer (peat whose decomposition degree R is up to 10%), thickness of the moss layer $h_2$ (the so-called „living turf") and the tree stem diameter. The Pressler drill was used to take a wood sample (the core) so as to see the core and all annual rings on the section (Fig. 3).

**Fig. 3. Diagram of collecting wood samples by means of the Pressler drill in the root neck of Scotch pine (Pinus sylvestris)**




h – thickness of acrotelm layer, $h_1$ – layer of peat with a degree of decomposition R up to 10%, $h_2$ – „living" turf layer

Altogether there were 21 trees (*Pinus sylvestris*) selected for measurements. For the trees measured, the basic descriptive statistics were calculated. Determination of the relations was preceded by examination of the normality of distribution of particular features, e.g. tree age and the acrotelm layer thickness above the root neck, by applying the W Shapiro-Wilk test. By means of the Cochran-Cox test with separate variance assessment, a comparison was made between the acrotelm layer thickness in selected zones of the profile. The STATISTICA 6.0 PL software package was used for the calculations.

The present plant cover on the research profile A-B was characterised by performing 12 phytosociological records by means of the commonly used Braun-Blanquet method.

## RESEARCH RESULTS AND DISCUSSION

### *The stand*

Characteristics of the selected elements of morphological structure for 21 pine trees on the research profile are presented in Table 1.

The structure of tree height is even $V_{height}$=26%. Due to the lack of accordance of the empirical distribution with the normal distribution (according to Shapiro – Wilk = 0.87; p<0.07), in order to determine the relation between tree height and tree crown length the Spearman coefficient of correlation was calculated. Its value amounts to $R_{height \leftrightarrow dł.}$=0.93. Such a strong linear relation of the above-mentioned features and similar values of the median (for the height $Me_{lenght}$=4.07) are evidence of weak clearing of lower branches from the trees. A possible reason is weak stand density.

An evident, larger differentiation of breast-height diameters in the stand in comparison with tree height (variability coefficient values: $V_{d.b.h.}$ = 41% and $V_{height}$ = 26% as well as Spearman R correlation coefficient values: R $Spearman_{d.b.h.}$=0.81) show that in the examined area there occurs a dynamic increment of tree thickness in comparison with tree height, which is visible in the even crown of the stand.

The root systems of the examined trees, flat and with a small horizontal range, which is visible after uncovering the root necks, are typical of ombrogenic bogs Tomanek [25].

**Table 1. Characteristics of selected elements of the morphological structure of trees (*Pinus sylvestris*) on the profile A – B (the peat bog „Bór za Lasem")**

| Trees | | | | | |
|---|---|---|---|---|---|
| No. | Breast-height diameter (cm) | Height (m) | Crown length (m) | Height of crown base (m) | Tree thickness on root neck level (cm) |
| 1 | 4 | 3 | 2.51 | 0.49 | 6.5 |
| 2 | 6 | 4 | 3.37 | 0.63 | 5.5 |
| 3 | 9 | 5 | 4.5 | 0.50 | 10.0 |
| 4 | 4 | 3 | 2.77 | 0.23 | 5.5 |
| 5 | 6 | 5 | 4.00 | 1.00 | 8.0 |
| 6 | 14 | 6 | 4.65 | 1.35 | 13.5 |
| 7 | 7 | 5 | 3.75 | 1.25 | 8.0 |
| 8 | 10 | 5 | 4.65 | 0.35 | 12.0 |
| 9 | 3 | 3 | 2.70 | 0.30 | 5.5 |
| 10 | 7 | 5 | 4.20 | 0.80 | 9.0 |
| 11 | 5 | 4 | 3.25 | 0.75 | 7.5 |
| 12 | 10 | 6 | 5.57 | 0.43 | 10.5 |
| 13 | 3 | 3 | 2.36 | 0.64 | 6.0 |
| 14 | 5 | 5 | 4.00 | 1.00 | 8.0 |
| 15 | 9 | 6 | 5.26 | 0.74 | 11.5 |
| 16 | 12 | 6 | 5.20 | 0.80 | 15.5 |
| 17 | 7 | 7 | 6.63 | 0.37 | 17.5 |
| 18 | 8 | 6 | 4.07 | 1.93 | 11.0 |
| 19 | 8 | 6 | 5.40 | 0.60 | 10.5 |
| 20 | 4 | 3 | 2.57 | 0.43 | 7.0 |
| 21 | 9 | 6 | 5.80 | 0.20 | 13.0 |

A flat root system is due to a high level of ground water on the bog's dome while limited growth of roots and needles is caused by a shortage of nitrogen and mineral salts Zgurowskaja [30]. Such a situation, however, does not significantly affect the tree stem increment and that is why the breast-height diameter of the examined trees was not positively correlated with the root size.

The age of the trees ranges from 15 to 41 years but it is the trees aged 20–30 years that are the most numerous. Considering the choice of trees for the measurements in various measurement classes, this testifies to the influence of bog microsites on tree growth. This may be confirmed by the lack of relation between tree age and breast-height diameter:

$$R_{age} \leftrightarrow {}_{d.b.h.} = 0.12.$$

***The acrotelm layer***

The thickness of the acrotelm layer at particular points (above the root neck) on the profiles and the annual increments are presented in Table 2.

The average thickness of the whole acrotelm layer amounted to 56.0 mm (with the liminal values from 20 to 160 mm).

Table 3 presents comparative data concerning the annual increments of the acrotelm layer, obtained by various authors on raised bogs in the Orawa-Nowy Targ Basin and the Bieszczady Mts.

**Table 2. Annual increment and thickness of the acrotelm layer above the root neck of trees on the dome of the peat bog „Bór za Lasem" (profile A – B)**

| Tree No. | Tree age (years) | Acrotelm layer thickness h (mm) | | | Annual increment (mm/year): | |
|---|---|---|---|---|---|---|
| | | $h_1$* | $h_2$** | $h=(h_1+h_2)$ | of whole acrotelm layer | of peat layer with R up to 10% |
| 1 | 20 | 50 | 20 | 70 | 3.5 | 2.5 |
| 2 | 20 | 80 | 20 | 100 | 5.0 | 4.0 |
| 3 | 41 | 90 | 40 | 130 | 3.17 | 2.2 |
| 4 | 25 | 80 | 60 | 140 | 5.6 | 3.2 |
| 5 | 36 | 30 | 20 | 50 | 1.39 | 0.83 |
| 6 | 27 | 130 | 20 | 150 | 5.56 | 4.81 |
| 7 | 28 | 90 | 30 | 120 | 4.29 | 3.21 |
| 8 | 25 | 80 | 40 | 120 | 4.8 | 3.2 |
| 9 | 22 | 90 | 40 | 130 | 5.9 | 4.09 |
| 10 | 15 | 110 | 40 | 150 | 9.3 | 7.33 |
| 11 | 28 | 110 | 40 | 150 | 5.36 | 3.93 |
| 12 | 18 | 120 | 40 | 160 | 8.88 | 6.67 |
| 13 | 24 | 100 | 40 | 140 | 5.83 | 4.17 |
| 14 | 30 | 110 | 30 | 140 | 4.67 | 3.67 |
| 15 | 20 | 100 | 30 | 130 | 6.5 | 5.0 |
| 16 | 24 | 50 | 20 | 70 | 2.92 | 2.08 |
| 17 | 33 | 110 | 20 | 130 | 3.94 | 3.33 |
| 18 | 20 | 30 | 0 | 30 | 1.5 | 1.5 |
| 19 | 29 | 50 | 0 | 50 | 1.72 | 1.72 |
| 20 | 17 | 150 | 0 | 150 | 8.82 | 8.82 |
| 21 | 28 | 20 | 0 | 20 | 0.71 | 0.71 |
| Mean: | | 85 | 32 | 56 | 4.7 | 3.7 |

* – peat layer with degree of decomposition R up to 10%

** – moss layer

R [%] – degree of decomposition

Most results are similar. It is worth noting the similarity of the results obtained on the dome of the bog „Bór za Lasem" by means of two different methods: the radiometric method by Boroń et al. [3] and the dendrological method by Lipka et al. [12]. The measurement of the acrotelm thickness in particular sectors of the profile showed certain differentiation. The average thickness of this layer found in the end sectors no. 1 and no. 4 was lower than in the central part of the profile (sectors 2 and 3).

In order to confirm this, researchers determined the following: the accordance of the distribution of this feature with the normal distribution in the sectors ($W_{1 \text{ and } 4} = 0.92$, $p = 0.29$; $W_{2 \text{ and } 3} = 0.93$, $p = 0.49$) and their different variances ($F = 14.36$, $p = 0.00$). The significance of differences in the average thickness of the acrotelm layer was determined using the Cohran-Cox test, where $t = 3.58$, $p = 0.00$.

Presumably, such differentiation of the thickness of the acrotelm in the peripheral and central sectors of the profile is closely related to the ground water level, which is usually higher in the central zone of the bog dome, as confirmed by field research (in the vegetation period of 2002, the ground water level ranged from 0.00 to 0.25 m). along the whole profile, the so-called hummock – hollow complex is almost not visible.

**Table 3. Comparison of annual increments of the acrotelm layer (above the root neck of trees) on the dome of the examined bogs in the Orawa-Nowy Targ Basin and the Western Bieszczady Mts**

| Orawa-Nowy Targ Basin | | | Western Bieszczady Mts | | |
|---|---|---|---|---|---|
| Tree name: *Pinus sylvestris* | | | Tree name: *Picea abies* | | |
| Bog name and measurement date | Average annual increment (mm/year) | | Bog name and measurement date | Average annual increment (mm/year) | |
| | of whole organic layer | of peat layer with R up to 10% | | of whole organic layer | of peat layer with R up to 10% |
| „Bór za Lasem" (radiometric method) 07–09. 2000. (Boroń et al. 2001) | 5.00 | | „Wołosate"<br>„Litmirz"<br>„Tarnawa"<br>07-08.2005 (Malec 2006) | 3.90<br>4.73<br>5.55 | 3.16<br>3.83<br>3.97 |
| „Bór na Czerwonem". „Pustać Chyżne". „Puścizna Mała". „Bór za Lasem". „Puścizna Rękowiańska" 07.2003. (Zając 2003) | 7.03 | 3.12 | | | |
| „Bór za Lasem" 08.2003. (Lipka et al.) | 4.70 | 3.70 | | | |

**Table 4. List of phytosociological records made at the peat bog „Bór za Lasem" in the Orawa – Nowy Targ Basin (in the profile A – B)**

| Species | Record no. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| | Number of species | | | | | | | | | | | |
| | 14 | 13 | 15 | 15 | 15 | 14 | 16 | 15 | 15 | 14 | 16 | 16 |
| *Sphagnum rubellum* | 1 | 1–2 | 3 | 4–5 | 5 | 5 | 5 | 5 | 3 | 2–3 | 2 | + |
| *S. cuspidatum* | 2 | 2–3 | 5 | 5 | 5 | 5 | 5 | 5 | 4–5 | 4 | 2–3 | 1 |
| *S. fallax* | + | 2 | 3 | 4–5 | 5 | 5 | 5 | 5 | 5 | 3–4 | 2 | 1 |
| *S. magellanicum* | 1 | 1–2 | 3–4 | 4 | 4–5 | 5 | 5 | 5 | 4–5 | 3 | 2 | 1–2 |
| *Sphagnum sp.* | 4–5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 |
| *Bryales sp.* | 1 | . | . | . | . | . | 1–2 | . | . | . | 1 | 1 |
| *Polytrichum communis* | . | . | . | 1 | . | . | . | . | . | . | . | . |
| *Cladonia pyxidata* | . | . | . | . | . | . | + | . | . | . | . | . |
| *Oxycoccus palustris* | 2–3 | 3–4 | 3 | 2 | 3 | 3 | 1–2 | 3 | 3 | 3 | 3 | 3 |
| *Empetrum nigrum* | . | . | 1 | 2 | . | 2 | 1 | 1–2 | 1 | 1 | 1–2 | 1–2 |
| *Andromeda polifolia* | 1 | 1 | 1–2 | 1 | 2–3 | 1 | 1 | 1 | 1 | 1 | | |
| *Vaccinium vitis– idaea* | 1 | 1 | 1 | 1 | 1 | . | . | . | . | . | 1 | 1 |
| *Vaccinium uliginosum* | 2 | 1–2 | 1 | 1 | 1 | 1 | 1–2 | 1–2 | 1 | 1 | 2 | 1–2 |
| *Calluna vulgaris* | 2 | 3 | 2–3 | 2–3 | 1 | 2 | 2–3 | 2–3 | 2 | 2 | 2–3 | 2 |
| *Ledum palustre* | 1–2 | 1–2 | 1 | 1 | + | 1 | 1–2 | 1 | 1–2 | 2 | 1–2 | 1 |
| *Drosera rotundifolia* | . | . | 1 | . | 1 | . | . | . | 1 | . | . | . |
| *Eriophorum vaginatum* | 2–3 | 3 | 2–3 | 2 | 2 | 3 | 2 | 2 | 2–3 | 2 | 2 | 3 |
| *Pinus mugo* | 1–2 | 1 | 1 | 1 | + | + | 1 | 2 | 1 | 1 | 1 | + |
| *Pinus sylvestris* | . | . | . | . | + | + | + | + | + | + | 1 | + |
| *Pinus uliginosum* | . | . | . | . | . | . | . | + | . | . | + | + |

The data in Table 2 show that the smallest annual increments of the acrotelm layer occurred in sector 4 in the southern part of the bog. This can be explained by the fact that the terrain adjacent to the present lagg is the area of the former bog, where peat has been exploited completely, down to the mineral level. At present, the dome edge, resulting from human activity, is extremely dry and degraded.

***The present state of the plant cover***

Researchers performed 12 phytosociological records on the profile. With respect to the area occupied, the dominant plants are the ones which belong to the class Oxycocco-Sphagnetea. The records are listed in Table 4. There is a well formed moss layer (*Sphagnum cuspidatum*, *S. rubellum, S. fallax* and *S. magellanicum*).

There also is an abundance of plants of the ericaceous family (*Ledum palustre, Oxycoccus palustris, Calluna vulgaris, Vaccinium uliginosum, Empetrum nigrum*). In some places, *Andromeda polifolia* is present in large amounts. Along the whole profile, *Eriophorum vaginatum* was also noted. In the top part of the bog dome are situated 5 small peat lakes with an area of several $m^2$ each, which for the last 20 years have been gradually taken over by land. Their depth had been diminishing and, simultaneously, the water table has been overgrown by a characteristic layer mostly formed by peat mosses: *Sphagnum cuspidatum, S. rubellum, S. fallax, S. magellanicum*. In the immediate neighbourhood of the lakes, a site of common sundew (*Drosera rotundifolia*) was noted. In regard to arborescent plants, the presence of *Pinus uliginosum* is a peculiarity (phytosociological records no. 11 and 12).

## CONCLUSIONS

1. Research concerning the increment rate of the acrotelm layer in the dome of the ombrogenic bog „Bór za Lasem" with the use of the dendrological method showed a large similarity of the results to the data obtained by Boroń et al. [3] by means of the radiometric method.
2. Examination of the plant cover on the characteristic profile proved that the dominant group is Oxycocco–Sphagnetea with a well formed layer of peat mosses. The abundant occurrence of species characteristic for the class Vaccinio uliginosi–Pinetum, such as *Vaccinio uliginosum, Ledum palustre, Oxycoccus palustrsi*, as well as a massive occurrence of arborescent plants (e.g. *Pinus sylvestris, Pinus uliginosum*) may testify to progressing succession towards coniferous bog forest, which is unfavourable from the point of view of organic matter accumulation.
3. Assessment of the stage of bog formation on the research profile shows that, despite the many years of former peat exploitation (in the northern part) on the bog dome, the peat-creating process has not stopped yet.
4. The examined bog constitutes a rarely encountered biocenosis and for this reason is has a large environmental significance. It has special aesthetic and landscape values, which make it unique. This object may be used for research and educational purposes. At the same time, it is proposed that the bog should be brought under legal protection, most desirably as a nature reserve.

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