NON-DESTRUCTIVE METHODS FOR PEAT LAYER ASSESSMENT IN OLIGOTROPHIC PEAT BOGS: A CASE STUDY FROM POIANA ŞTAMPEI, ROMANIA

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ABSTRACT

Practices currently employed in the investigation and characterisation of peat deposits are destructive and may irremediable perturb peat bog development even in cases when exploitation is not carried out. We investigated the correlation between vegetation characteristics in the active area of Poiana Ştampei peat bog, Romania, and the underlying peat layer depth, aiming at establishing a non-destructive method of peat layer depth estimation. The presence of the Sphagneto-Eriophoretum vaginati association, dominated by *Sphagnum fimbriatum*, *Eriophorum vaginatum*, *Andromeda polifolia*, *Vaccinium oxycoccos*, *V. myrtillus*, *V. vitis-idaea*, *Polytrichum commune*, *Picea excelsa*, *Pinus sylvestris* and *Betula verrucosa* was found to predict the existence of the peat layer but not its depth. Out of the seven identified vegetation types, one type was associated with a very thin or no peat layer, one type was characterised by the presence of a thick (over 100 cm) peat layer and five types indicated the presence of variable average depths of the peat layer. pH values correlated with peat layer depth only within the vegetation type associated with thick peat layers.

KEY WORDS: classification system, plant community, similarity, *Sphagnum fimbriatum*.

INTRODUCTION

Peat bogs are complex ecosystems formed during long term interactions of multiple factors such as topographical, hydrological and vegetation related factors.

Excess of humidity is a prerequisite of peat bog genesis and maintenance, since it greatly influences vegetation structure as well as peat accumulation and decay. Therefore, any decline of humidity conditions caused by draining will eventually disturb the bog's equilibrium. Changes in land use practices of the peat bog or of the catchment area can also result in serious alterations of the vegetation structure (Chapman 1991).

Designing sustainable exploitation strategies of peat deposits depends on the availability of consistent data on quantity and quality of the peat deposit. Classical methods used for this type of investigations involve probing the peat layer. The unavoidable associated risk of such destructive techniques is the perforation of the impermeable foundation of the peat bog and the consequent drainage and disturbance of the peat genesis processes.

The present study aims at establishing a non-destructive method for the assessment of peat layer depth, based on the correlation between vegetation characteristics and the underlying substrate. Conditioning of vegetation patterns by stratigraphy and hydrological factors was already investigated in several studies (Heinselman 1970; Comas 2004), but no such non-invasive method has been reported so far, to our knowledge.

Poiana Ştampei (47°20'N, 25°15'E) is an oligotrophic peat bog formed through the paludification of a spruce forest situated on flat terrain with an impermeable clay layer covering the underlying rock. It is one on the largest peat bogs in Romania and part of a scientific reserve. The marsh forming was conditioned by the local climatic conditions (excessive humidity caused by prolonged heavy rain periods) and topologic factors (the area is situated on the terrace of two rivers, at the confluence of Dorna and Dornişoara; its foundation lies above the rivers' level). The genesis of the peat bog is confirmed by presence of a trunk layer at the foundation of the peat deposit (Pop 1960).

The peat bog is situated at 910 m altitude, is elliptically shaped and occupies 612 ha, 400 ha of which represent its active area (Pop 1960). Early studies of the peat deposit (Pop 1950, 1960) revealed its three layered structure: a few meters deep sedge peat covered by 1.5-2 m of old *Sphagnum* peat and 2-4 m of new *Sphagnum* peat.

The main vegetation association in the peat bog is Sphagneto-Eriophoretum vaginati, defined by: *Sphagnum medium*, *S. fuscus*, *S. fimbriatum*, *Eriophorum vaginatum*, *Empetrum nigrum*, *Andromeda polifolia*, *Vaccinium oxycoccos*, *V. myrtillus*, *V. vitis-idaea*, *Polytrichum commune*, *Picea excelsa*, *Pinus sylvestris*, *Betula pubescens*, *B. verrucosa* (Pop 1960).

Understanding peat bog genesis and evolution is a prerequisite for ecological reconstruction of deteriorated peat bogs (Janssens 1983). The efficiency of peat bogs as information storage environment regarding ecological succession and in situ preservation environment for glacial relicts adds to their economic value (Nastac 1973). The extreme environmental conditions (extreme low pH between 4 and 5.2, anoxia and oligotrophy) created by the water over saturation of the *Sphagnum* layer allowed for a rather reduced and very characteristic vascular flora. These same conditions ensured good conservation of detritus below few cm depth, where the anoxia and acidity strongly limit the development of bacterial flora and the intensity of decomposition processes. The peat environment offers optimal conditions for the preservation of spores, pollen and seeds, storing thus valuable information allowing for the inference of evolutionary scenarios (Glebov 2002).

Hence, the development of non-destructive methods for peat layer depth estimation is of great importance for the preservation of peat bogs.

MATERIAL AND METHODS

The field study was performed in August 2003, as part of a more complex analysis of the peat bog. We investigated the vegetation structure (including identification of plant species, classification in vegetation types and associations, vegetation mapping) and also, the existence of correlations between vegetation structure and peat layer depth.

The study was concentrated on the peat bog's active area, which was divided in 86 plots (10 000 m^2 each). The peat layer depth was measured in the centre of each plot. pH, organic substance and the oxygen dissolved in the interstitial water were also determined for each plot.

Vegetation types were identified by cluster analyses based on the species composition of the plots using Jaccard's coefficient as binary similarity measure and UPGMA as clustering algorithm. After assigning the vegetation type to each plot, the vegetation and the peat layer depth were mapped.

To test for differences in the peat layer depth underneath the seven vegetation types, we used a linear model with peat layer thickness as dependent variable and vegetation type as predictor while controlling in the full model for phisico-chemical parameters (pH, dissolved oxygen and organic substance). We used single degree of freedom comparisons (i.e. treatment contrasts, Crawley 2002) to look for differences among vegetation types. Model simplification was performed according to Crawley (Crawley 2002). In the

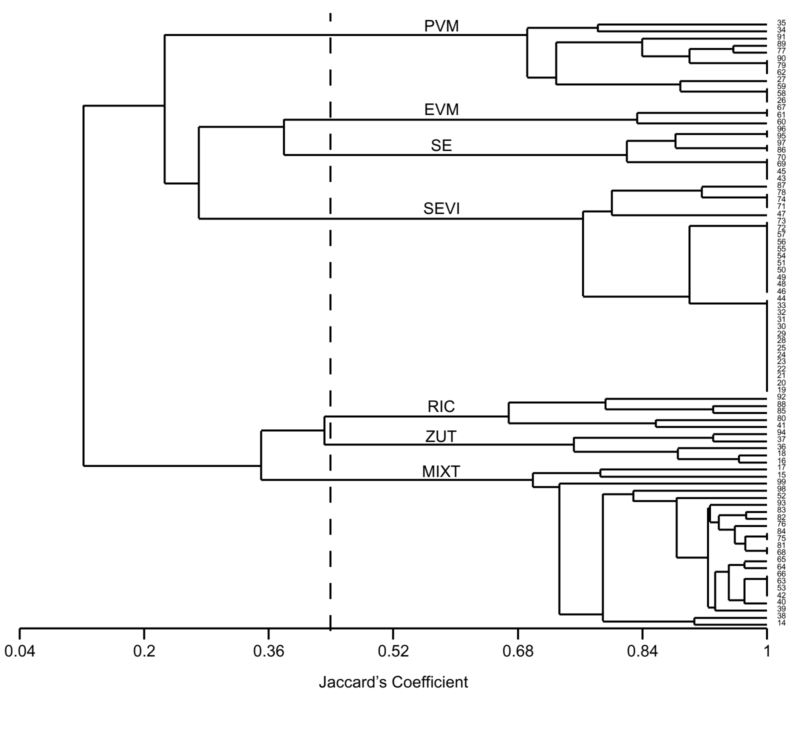

Fig. 1. Identification of vegetation types by cluster analyses based on the species composition of the plots.

TABLE 1. Species composition of the seven vegetation types identified in Poiana Ştampei peat bog.

Species	Vegetation type						
	MIXT	ZUT	SE	PVM	SEVI	RIC	EVM
Tree layer							
Alnus incana	+	–	–	–	–	–	–
Betula humilis	–	–	–	–	+	–	–
Picea excelsa	+	+	+	+	–	–	–
Pinus sylvestris	–	–	+	–	+	–	–
Shrub layer							
Spirea chamaedryfolia L.	+	–	–	–	–	+	–
Viburnum opulus L.	+	–	–	–	–	–	–
Herbaceous layer							
Cryptogams							
Cl. Dicotyledoneae							
Fam. Asteraceae (Compositae)							
Aster alpinus L.	+	–	–	–	–	–	–
Bellis perennis L.	+	–	–	–	–	–	–
Centaurea kotschyana Heuffel	–	–	–	–	–	+	–
Cirsium canum L.	+	–	–	–	–	–	–
Cirsium oleraceum (L.) Scop.	+	+	–	–	–	+	–
Hieracium pilosella L.	+	+	–	–	–	–	–
Inula britannica L.	+	–	–	–	–	+	–
Senecio nemorensis L.	+	+	–	–	–	+	–
Fam. Boraginaceae							
Lithospermum officinale L.	–	–	–	+	–	–	–
Myosotis silvatica (Ehrh.) Hoffm.	+	+	+	–	–	–	–
Symphytum cordatum Waldst. et Kit.	+	–	–	–	–	–	–
Fam. Caryophyllaceae							
Stellaria palustris Retz.	+	–	–	–	–	–	–
Fam. Campanulaceae							
Campanula abientina Griseb.et Sch.	+	–	–	–	–	–	–
Campanula glomerata L.	+	–	–	–	–	–	–
Campanula patula L.	+	–	–	–	–	–	–
Fam. Droseraceae							
Drosera rotundifolia L.							
Fam. Ericaceae							
Andromeda polifolia L.	–	–	–	–	+	–	–
Vaccinium myrtillus L.	+	+	+	+	+	+	+
Vaccinium oxycoccos L.	+	–	–	–	+	–	–
Vaccinium vitis-idaea L.	–	–	+	+	+	–	+
Fam. Hypericaceae							
Hypericum perforatum L.	+	+	–	–	–	+	–
Fam. Labiatae							
Galeopsis speciosa Mill.	+	+	–	–	–	–	–
Mentha longifolia L.	+	–	–	–	–	–	–
Prunella vulgaris L.	+	–	–	–	–	–	–
Fam. Onagraceae							
Circaea lutetiana L.	+	–	–	–	–	–	–
Epilobium alpinum L.	+	+	+	+	–	–	–
Epilobium nutans F.W. Schmidt	–	+	–	–	–	–	–
Fam. Oxalidaceae							
Oxalis acetosella L.	+	–	+	+	–	+	–
Fam. Polygalaceae							
Polygala amara L.	+	–	–	–	–	–	–
Fam. Primulaceae							
Lysimachia thyrsiflora L.	+	+	+	–	–	–	–
Fam. Ranunculaceae							
Caltha palustris L.	–	+	–	–	–	–	–
Ranunculus platanifolius L.	+	+	+	–	–	–	–
Fam. Rosaceae							
Alchemilla vulgaris L.	+	–	–	–	–	–	–
Filipendula ulmaria L.	+	+	–	–	–	+	–
Fragaria vesca L.	+	–	–	–	–	+	–
Rubus idaeus L.	+	+	–	+	–	+	–
Fam. Rubiaceae							
Asperula taurina L.	+	–	–	–	–	+	–
Galium palustre L.	–	–	–	–	–	+	–

TABLE 1. Cont.

Species	Vegetation type						
	MIXT	ZUT	SE	PVM	SEVI	RIC	EVM
Fam. Urticaceae							
Urtica dioica	+	–	–	–	–	–	–
Cl. Monocotyledoneae							
Fam. Cyperaceae							
Carex diandra Schrank	+	+	–	+	–	+	–
Carex flava L.	+	+	–	+	–	+	–
Carex nigra L.	+	+	–	–	–	+	–
Carex riparia L.	+	+	–	+	–	+	–
Eriophorum vaginatum L.	–	–	+	+	+	–	–
Scirpus silvaticus L.	+	+	–	–	–	–	–
Fam. Graminaceae							
Agrostis tenuis Sibth.	+	+	–	–	–	+	–
Calamagrostis arundinacea (L.) Roth	+	+	+	+	–	+	–
Cynosurus cristatum L.	+	–	–	–	–	–	–
Poa annua L.	+	+	–	–	–	+	–
Poa palustris L.	+	–	–	–	–	–	–
Fam. Juncaceae							
Juncus conglomeratus L.	–	+	–	–	–	–	–
Juncus effusus L.	–	+	–	+	–	–	–
Luzula sylvatica L.	+	+	–	+	–	+	–
Fam. Liliaceae							
Majanthemum bifolium (L.) Schm.	+	+	–	–	–	+	–
Veratum album L.	+	–	–	–	–	–	–
Fam. Typhaceae							
Typha latifolia L.	–	+	–	–	–	–	–
Ground layer							
Phylum Bryophyte							
Ctenidium molluscum Hedw.	–	–	–	+	–	–	–
Mnium affine L.	+	+	–	+	+	+	–
Orthothecium rufescens Brid.	–	–	–	+	–	–	–
Pleurozium schreberi (Brid.) Mitt.	+	+	+	+	+	+	+
Polytrichum commune Hedw.	+	+	+	+	+	+	+
Ptilium crista-castrensis (Hedw.) DeNot.	–	–	–	+	–	–	–
Sphagnum auriculatum Schimp.	–	–	–	+	–	–	–
Sphagnum fimbriatum Wils.	+	+	+	+	+	+	+
Sphagnum palustre L.	+	–	–	+	+	–	–
Pteridophyta							
Fam. Lycopodiaceae							
Lycopodium annotinum L.	+	–	–	+	–	–	–
Fam. Equisetaceae							
Equisetum hyemale L.	–	–	+	–	–	–	–
Equisetum palustre L.	–	–	+	–	–	+	+
Equisetum pratense L.	+	+	+	+	+	+	–
Fam. Polypodiaceae							
Cystopteris fragilis (L.) Bernh.	+	–	–	+	–	–	–
Dryopteris filix-mas (L.) Scott.	+	–	–	+	–	+	–
Thelypteris phegopteris L.	+	–	–	+	–	–	–

minimal model only vegetation type and pH were retained. Statistical analyses were performed with MVSP version 3.13 m (Kovach Computing Services 2004) and R (R Development Core Team 2005).

Additionally, we searched for species or groups of species that can predict the peat layer depth. For this purpose, we screened for species or groups of species that fulfil a series of criteria that would qualify them as potential markers for the peat layer depth: the species should be characteristic for a unique vegetation type and occur in all the plots of that type, they should always co-occur and their occurrence should be restricted to a certain range of peat layer depths.

RESULTS

Vegetation characterisation

On the basis of floristic criteria, the cluster analyses identified seven types of vegetation (Fig. 1, Table 1). The clusters were unambiguously defined by coefficients of similarity lower that 0.40. The following characterisation of the vegetation types supplements Table 1.

I. MIXT classified as: Sphagno-Piceetum association (Coldea 1991)

The tree layer is dominated by *Picea excelsa*, with few *Alnus incana* (characteristic for this vegetation type) individuals at the forest skirts. Compared to the other vegetation types, the herbaceous layer of MIXT vegetation is characterized by a higher diversity and a relative higher equitability. Biomass dominant species are *Oxalis acetosella*, *Pleurozium schreberi* and *Polytrichum commune*.

II. ZUT classified as: Epilobio-Juncetum effusi (Coldea 1991)

Wetland dominated by *Typha latifolia* and other wetland characteristic species (*Juncus effusus*, *Scirpus silvaticus*, *Typha latifolia*, *Carex riparia*, *Epilobium nutans*) accompanied by five *Carex* species, this vegetation type lacks almost completely the moss layer. *Picea excelsa*, *Pinus sylvestris* and *Betula humilis* form the tree layer. It mostly occupies the small valleys.

III. SE classified as: Molinietalia (Coldea 1991)

The tree layer is represented by *Picea excelsa*, *Pinus sylvestris*. The herbaceous layer diversity is low and dominated by *Equisetum palustre* and *Sphygnum fimbriatum*, with seldom occurrence of *Lysimachia thyrsiflora*. *Pleurozium schreberi*, *Polytrichum commune* appear at low frequencies in the ground layer, covering decomposing trunks. Occasionally, *Vaccinium myrtillus* accompanies fallen trunks.

IV. PVM classified as: Vaccino-Piceetalia (Coldea 1991)

The tree layer is represented exclusively by *Picea excelsa*. *Polytrichum commune* and *Vaccinium myrtillus* dominate the herbaceous layer. Moss species as *Pleurozium schreberi*, *Mnium affine*, *Ptilium crista-castrensis* and *Ctenidium molluscum* (the last three species are characteristic for this vegetation type) form, at low abundance, the ground layer, while higher species are underrepresented.

V. SEVI classified as: Sphagnetalia (Coldea 1991)

This vegetation type is the most widely spread in the study area. It is characterised by the lowest diversity. The tree layer is represented by *Pinus sylvestris* and *Betula humilis* (characteristic for this vegetation type), while the herbaceous layer is dominated by *Sphagnum fimbriatum*, *Vaccinium vitis-idaea*, *Eriophorum vaginatum* with seldom occurrence of *Andromeda polifolia* (characteristic for this vegetation type) and *Vaccinium oxycoccos*. *Sphagnum palustre* was also encountered at very low abundance.

VI. RIC classified as: Calamagrostio arundinaceae – Spiretum ulmifoliae (Resmerita and Csuros 1966)

This vegetation type occupies small areas in the spruce forest (*Picea excelsa*) where fallen trunks created good illumination conditions. The shrub layer is dominated by *Rubus idaeus* accompanied, at lower abundances by *Spirea chamaedryfolia*, while the herbaceous layer is dominated by *Calamagrostis arundinacea*, accompanied by *Agrostis tenuis*, *Poa annua*, *Luzula sylvatica* and *Carex riparia*.

VII. EVM classified as: Myrtillo-Pinetum (Burduja and Stefan 1982)

The herbaceous layer is dominated by *Equisetum palustre* and *Vaccinium myrtillus*. *Sphagnum fimbriatum*, *Polytrichum commun* and *Pleurozium schreberi* were also encountered at very low abundances.

Among the encountered species 42.9% (33 species) were characteristic for one single vegetation type; the rest of 57.1% (44 species) were present in plots of two or more vegetation types. 45 to 83% of the species identified for each vegetation type were present all the plots that belonged to that particular type.

Some characteristics of the vegetation types with respect to the species composition are presented in Table 2.

Vegetation type and peat layer depth

We found that peat layer depth is predicted by vegetation type and pH. We also found a significant interaction between vegetation type and pH ($F_{2, 80} = 13.06$, $p<0.001$). Peat layer depth was significantly correlated with pH only for the SEVI vegetation type (slope estimate = -98.48±30.29; t = -3.251; p = 0.002; $R^2 = 0.314$) and not for the other vegetation types (t = -0.067; p = 0.947).

We classified the seven vegetation types identified in three categories according to the depth of the corresponding peat layer:

I. Vegetation types with no or very small peat layer: MIXT

II. Vegetation types with average (10-85 cm) peat layer: EVM, PVM, SE, ZUT, RIC

III. Vegetation types with thick peat layer: SEVI

The thickness of the peat layer under the MIXT vegetation type was found to be significantly smaller (p=0.040) than that under the other six vegetation types (Fig. 2). The SEVI vegetation type was associated to the thickest peat layer. The difference in peat layer thickness between SEVI and the other six vegetation types was highly significant (p<0.001) (Fig. 2).

While the five vegetation types associated with average peat layer thickness can predict the presence but not the thickness of the peat layer, the other two vegetation types have higher predictive values: the MIXT vegetation pre-

TABLE 2. Parameters that characterise the seven vegetation types identified in Poiana Ştampei peat bog.

Vegetation type	MIXT	ZUT	SE	PVM	SEVI	RIC	EVM
No. of plots	23	5	8	12	30	5	3
Min no. of species/plot	30	27	14	16	9	18	5
Max no. of species/plot	42	30	16	25	12	29	6
Mean no. of species/plot	35	28	15	21	10	24	6
Total no. of species	58	33	17	28	13	29	6
No. of species specific to the vegetation type	19	4	1	5	2	2	0
Mean peat layer depth	6.3	59.0	47.5	45.0	150.8	63.0	42.7
Range of peat layer depth	0-50	45-70	27-70	10-80	100-230	40-85	18-60
pH ± SD	7.2±0.2	6.3±0.1	5.6±0.2	5.4±0.1	4.5±0.3	6.7±0.1	6.3±0.1
Dissolved oxygen (mg/l) ± SD	6.65±0.34	3.50±1.36	1.71±0.37	2.71±0.26	1.02±0.29	5.34±0.30	4.45±0.14
Organic substance (μgC/g dried sample) ± SD	121.2±115.4	257.4±8.5	427.6±17.0	272.2±37.5	650.0±19.6	171.8±36.9	159.7±2.1

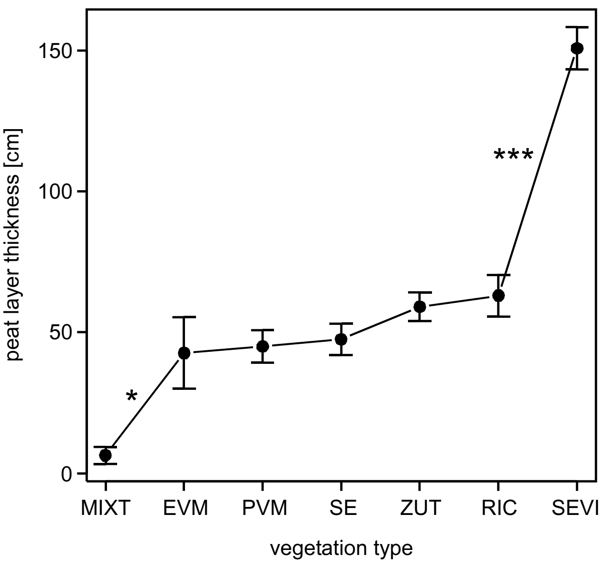

Fig. 2. Correlation between peat layer depth (average ±SEM) and vegetation type.

dicts the absence of the peat layer (83% of cases) or no more than a thin layer, and the SEVI vegetation predicts peat layers thicker than 100 cm (up till 230 cm in our study area).

A detailed examination of the peat layer depth and vegetation type mapping (Fig. 3) confirmed that SEVI vegetation occupies the areas with the thickest peat layer and MIXT vegetation covers areas lacking the peat layer or with very thin peat layers.

Plant species occurrence and peat layer depth

The analyses at species level revealed groups of species that could function as markers for peat layers of different depths.

Betula humilis and *Andromeda polifolia* co-occurred and were found to be characteristic for the SEVI vegetation type and for plots with peat layer between 100 and 230 cm depth.

Another eight species were found to be characteristic for the MIXT vegetation type: *Alchemilla vulgaris*, *Bellis perennis*, *Campanula abientina*, *Campanula glomerata*, *Mentha longifolia*, *Prunella vulgaris*, *Symphytum cordatum* and *Urtica dioica*. They co-occurred in all plots with MIXT vegetation (exception: *Campanula glomerata* present in only 95.7% of plots) and no peat layer (82.6%) or low depth (25-50 cm) peat layers (17.4%).

Although we found no species or combinations of species that could be used as markers for medium depths of the peat layer irrespective of the vegetation type, we were able to assign "marker" species to two of these vegetation types. Following the same criteria, *Epilobium nutans* and *Typha latifolia* were found to be characteristic for ZUT vegetation type and peat layers between 45 and 70 cm, and *Centaurea kotshyana* was characteristic for RIC vegetation type and for peat layers between 45 and 70 cm. It should be, nevertheless, mentioned that in the case of ZUT and RIC vegeta-

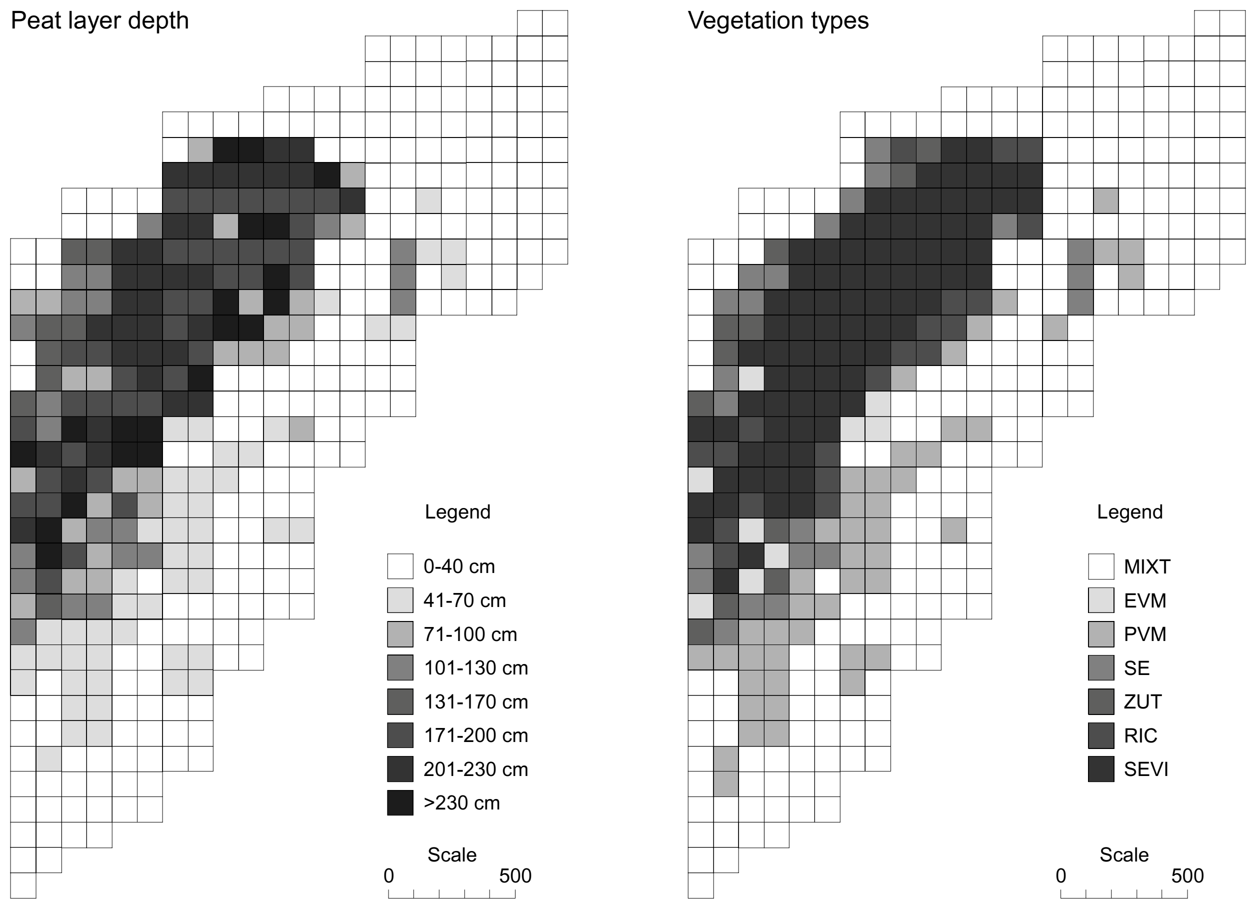

Fig. 3. Peat layer depth and vegetation types mapping in Poiana Ştampei peat bog.

tion the identification of these species was based on a small number of plots (5 for each vegetation type), so the reliability of these findings should be further checked.

CONCLUSIONS

Following an extensive study of Poiana Ştampei peat bog, seven vegetation types were identified.

Certain vegetation types were found to predict the presence of the peat layer but, except for wide ranges, not its thickness. One of the vegetation types (MIXT) indicates the absence of the peat layer or the existence of very thin peat layer. The SEVI vegetation type was found to be associated with peat layers deeper than 100 cm, and other five vegetation types (EVM, PVM, SE, ZUT and RIC) were found to indicate the presence of medium sized peat layers.

Our results clearly indicate that certain vegetation types can be used as predictors for the presence of the peat layer. In the case of one vegetation type (SEVI) the predictive value extends to predicting a minimum depth of the peat layer. The range of pH value has the same predictive value for the presence of peat layer depth as the SEVI vegetation type (values lower than 5 predicted the presence of peat layers thicker than 1m) while the real depth of the peat layer can be predicted by the pH value only within SEVI vegetation type. Assessments of the vegetation structure could therefore replace the destructive methods currently used for evaluation of peat bog areas with respect to peat layer presence and depth and pH measurements in areas with a certain vegetation cover can provide more detailed information concerning the peat layer depth. This approach could be particularly useful since large scale assessment of vegetation cover at the landscape level is nowadays widely available and can be rapidly performed (e.g. based on satellite images).

Although we consider Poiana Ştampei peat bog as being representative for this type of ecosystems, the effectiveness of the proposed method has to be further confirmed for similar peat bog areas.

LITERATURE CITED

BUEDUJA C., STEFAN N. 1982. Cercetări fitocenologice asupra pinetelor din bazinul superior al râului Rîmnicu Sărat. Culegere de studii şi articole de biologie, Univ. Al. I. Cuza – Grădina Botanică. 2: 234-242. (in Romanian with French summary)

CHAPMAN S.B., ROSE R.J. 1991. Changes in the vegetation at Coom Rigg moss national nature reserve within period 1958-1986. J. Appl. Ecol. 28: 140-153.

COLDEA G. 1991. Prodrome des associations vegetales des Carpates du Sud-Est (Carpates Roumaines). Documents phytosociologiques, Nouvelle Serie. 13. Camerino Universita degli Studi.

COMAS X., SLATER L., REEVE A. 2004. Geophysical evidence for peat basin morphology and stratigraphic controls on vegetation observed in a northern peat bog. J. Hydrol. 295: 173-184.

CRAWLEY M.J. 2002. Statistical computing: an introduction to data analyses using S-plus. John Wiley & Sons, New York.

GLEBOV F.Z., KARPENKO L.V., DASHKOVSCAYA I.S. 2002. Climatic changes, succession of peat bogs and zonal vegetation, and peat accumulation dynamics in the Holocene. The West-Siberia Peat profile 'Vodorasdel'. Clim. Chem. 55: 175-181.

HEINSELMAN M.L. 1970. Landscape evolution, peat bog types and the environment in the Lake Agassiz peat bogs natural area, Minnesota. Ecol. Monographs. 40: 235-260.

JANSSENS J.A. 1983. Quantitative Method for Stratigraphic Analysis of Bryophytes in Holocene Peat. J. Ecol. 71: 189-196.

Kovach Computing Services. 2004: MVSP Version 3.13m. http://www.kovcomp.com

POP E. 1950. Turbăriile din Bazinul Dornelor. Travaux de Biologie. 3: 46-55.

POP E. 1960. Mlaştinile de turbă din Republica Populară Română. Ed. Republicii Populare Române (in Romanian with German summary)

RESMERITA I., CSUROS S. 1966. Cartarea geobotanică şi agrotehnică a corpului de păşune Cioaca-Huiedin. Contribuţii Botanice. 2: 91-102. (in Romanian with English summary)

NĂSTAC C. 1973. Actualitatea vechilor turbării din judeţul Suceava. Stud. şi comun. Ocrotiea Naturii. 3. (in Romanian with French summary)

R Development Core Team. 2005. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0. URL _ HYPERLINK "http://www.R-project.org"