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APPLICATION OF MULTIDIMENSIONAL STATISTICAL METHODS IN ANALYSES OF PEAT GEOCHEMICAL FEATURES

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SUMMARY

Multidimensional statistical methods provide the best way to analyse and understand complex matrixes of data. Especially, when studied variables are interrelated and cannot be interpreted separately as in case of peat geochemical features. Mulitdimensional analyses showed that pH values of examined peats were more strongly related to water regime than to biomass compositon. For decomposition degree there was an opposite relation. pH value was a main factor influencing total lipid content. Decomposition degree shaped the amounts of humic substances in peats. Organic matter content was under strong influence of both pH value and decomposition degree.

KEYWORDS: peat, geochemistry, multidimensional analyses

INTRODUCTION

Geochemical features of peats, in both qualitative and quantitative way, depend strongly on direction and intensity of decomposition proccesses. They, in turn, are shaped by habitat conditions (e.g. moisture, temperature), and by chemical composition of degrading plant biomass, which results from floristic composition of peat-forming plant communities. Therefore, habitat conditions during time of deposition and, formed under their influence, floristic composition of plant communities can be acknowledged as two main drivers of peat geochemical features. These two factors are interrelated, which makes their separate impacts on peat-forming processes hard to distinguish. Moreover, peat-forming plant communities may modify existing environmental conditions e.g. by drying out and increasing oxygen amount in peat deposit (trees) or by further acidifying sediments (*Sphagnum* mosses). Though there are numerous studies of geochemical features of peats deposited under particular habitat conditions or from biomass of a particular origin, the researchers very seldom try to assess how strongly each of the drivers influences chemistry of peats. Hereby we attempt to estimate separate impacts of habitat conditions and biomass composition on peat geochemical features by means of multidimensional statistical methods.

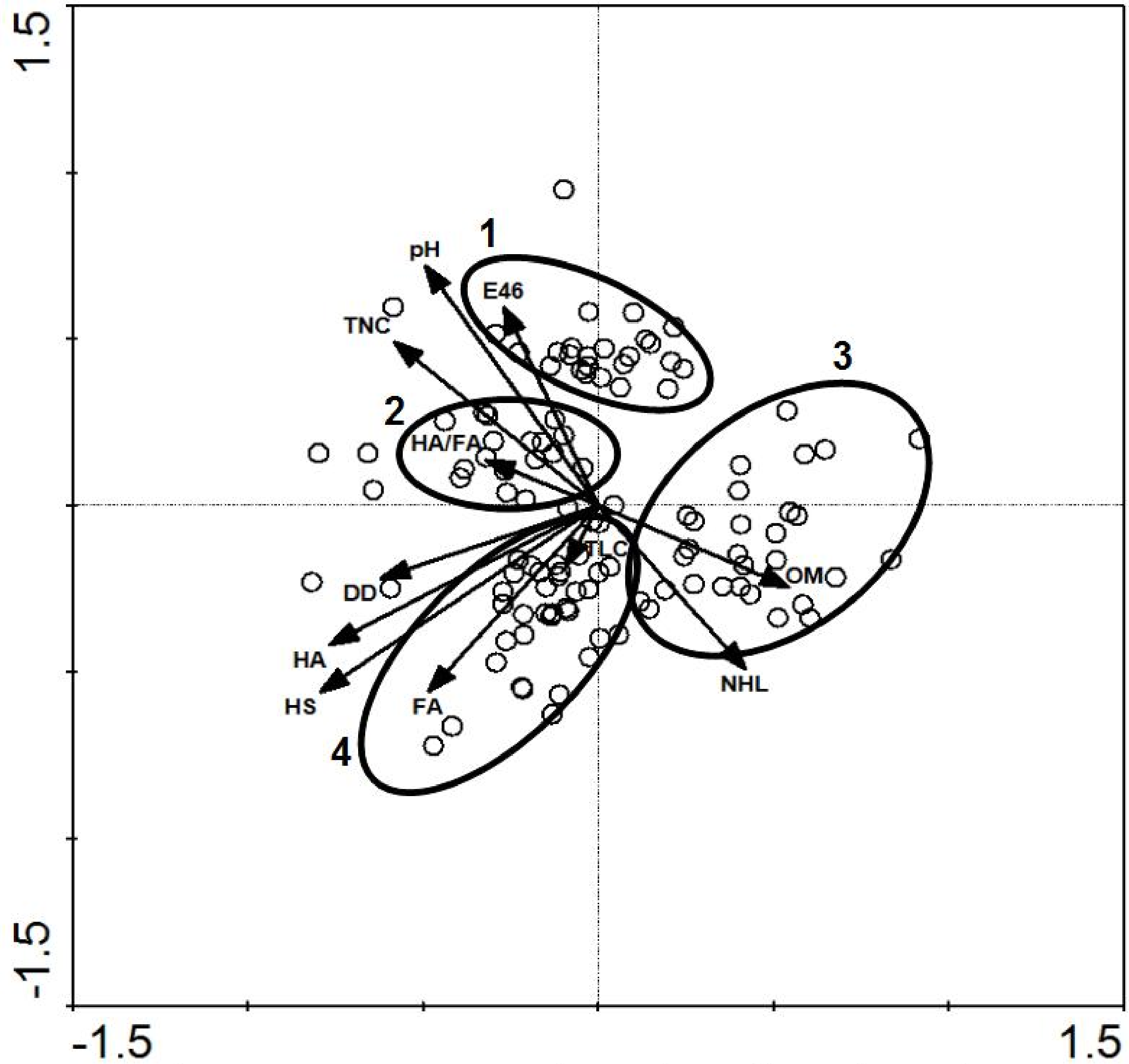
MATERIALS AND METHODS

Peat samples were collected from 18 Polish peatlands, characterized by different genesis, water regime and intensity of human impact. Altogether 111 peat samples were taken with the use of an Instorf sampler. They represented distinct types and groups of peats according to the Polish peat classification. Organic matter properties of the samples were examined by measuring decomposition degree (Okruszko, 1974), humic substances content (Kononova 1968), total lipids content, non-hydrolysable lipids content and by conducting standard geochemical analyses - pH value, ash content, total nitrogen content (Ostrowska et al., 1991; Sapek and Sapek, 1997). Acquired data matrix was subjected to a series of principal component analysis (PCA), linear discriminant analysis (LDA) and redundancy analysis (RDA) in CANOCO 4.5.

RESULTS

In order to discover inner diversity patterns in the data matrix, PCA was conducted, with geochemical features as dependent variables (Fig.1).

Accordingly, four clusters of samples can be distinguished: (1) consisting of brown moss and herbaceous fen peats, (2) consisting of herbaceous fen peats, (3) consisting of *Sphagnum* moss raised bog peats and (4) comprising herbaceous raised bog peats. Samples of forest and transition peats are scattered randomly over the diagram. Observed pattern corresponds to the German peat classification, which is based both on habitat (species groups) and botanical criteria (species units) (Bodenkundliche Kartieranleitung, 1996). Therefore, ordination axes in the performed PCA mirror differences in habitat conditions and in floristic composition of studied peats. Hence, the German system may provide approximate means to separately estimate the impact of habitat conditions (species groups) and floristic composition of plant biomass (species units) on peat geochemical features. To determine by which features distinctions can be made among species groups, and by which features among species units, linear discriminant analyses with forward selection were performed. Studied species groups (fen, transition and raised bog peats) differed significantly in pH values, total nitrogen content and fulvic acids content. pH values, being the highest in fen peats samples and the lowest in raised bog peat samples, explained 35% of the total observed variance among species groups (p=0,002). Total nitrogen content explained 6,9% of the total observed variance (p=0,002), with the highest values in fen peat samples and the lowest in raised bog peat samples. The highest amount of fulvic acids was noted in transition peats. For raised bog and fen peats the amount of fulvic acids was comparable. Fulvic acids content explained 2,4% of the total observed ariance (p=0,02). The same analyses were performed for species units and showed that they differ significantly in decomposition degree, organic substances content, humic substances content and total lipids content. Both decomposition degree and humic substances content increased in the following order moss peats<herbaceous peats<forest peats. Decomposition degree explained 9,4% of the total observed variation (p=0,002) and humic substances content 2,5% of the total observed variation (p=0,034). The highest total organic matter content and total lipid content were observed in herbaceous peats and the lowest in woody peats. Organic matter content explained 3,9% of the total observed variation (p=0,016) and total lipid content 2,1% of the total observed variation. Thanks to the forward selection



Axis	1	2	3	4
Eigenvalue	0,278	0,210	0,143	0,100
Cumulated % of variance	27,8	48,8	63,1	73,1

Fig.1 PCA diagram showing clusters of samples. Dependant variables in alphabetical order: decomposition degree (DD), fulvic acids (FA), humic acids (HA), humic acids to fulvic acids ratio (HA/FA), humic substances (HS), non-hydrolysable lipid content (NHL), pH, ratio of humic substances absorbance at 465 λ to their absorbance at 665 λ (E46), total organic matter (OM), total nitrogen content (TNC), total lipid content (TLC).

step, variance explained by each variable is counted separately and the percentages explained by other variables are excluded.
To study interdependence among particular geochemical features of peat, redundancy analyses were performed (Fig. 2).

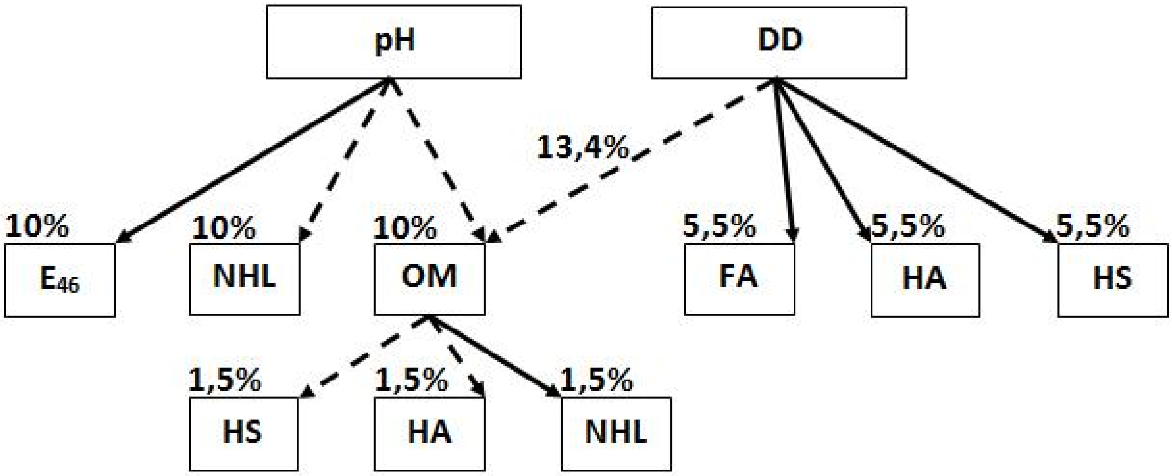


Fig. 2. Factors influencing geochemical features of peat. Solid lines signify positive relation, dotted lines – negative relation. Numbers given are percentages of variation explained by particular independent variables. All realtions shown are statistically significant ($p<0,05$). Variables in alphabetical order: decomposition degree (DD), fulvic acids (FA), humic acids (HA), humic substances (HS), non-hydrolysable lipid content (NHL), pH, ratio of humic substances absorbance at 465 λ to their absorbance at 665 λ (E46), total organic matter (OM).

Basing on this set of analyses, it can be stated that highly acidic peats were rich in organic substances, including non-hydrolysable lipids. The amount of humic substances in highly acidic peats was low, with domination of aromatic compounds (low values of $E_{4/6}$ ratio). On the contrary, in highly decomposed peats the amount of organic substances was low, however the amount of humic substances was high.

DISSCUSSION

Since pH values differed significantly among distinguished peat species groups, it can be stated their changes are shaped mostly by environmental conditions during time of deposition. Raised bog peats are formed under ombrotrophic conditions. During deposition time they are regularly rinsed with precipitation, which ussually washes out highly acidic mor type litter from surounding coniferous forests. On the contrary, fen peats are deposited on the peatlands connected with rivers, lakes or fed by ground waters.These water sources tend to be less acidic and much more fertile. Thanks to their specific water regime and high intensity of decomposition processes, fens are quite rich in allochtonous mineral nitrogen forms. Oppositely, ombrotrophic bogs are characterized by insignificant allochtonous nitrogen inflow combined with slow rates of decomposition, which results in prevalence of organic nitrogen forms in peat (Ilnicki, 2002; Bayley *et al*., 2005). LDA showed that total nitrogen content is also a habitat-dependent feature of peats.

Basing on the fact that decomposition degree and features which characterize composition of organic matter varied significantly among different peat species units, it can be assumed that their changes depend mostly on botanical composition of peats. The slowest decomposition rate and the highest organic substances content were observed in moss peats (both brown and *Sphagnum* moss). Thanks to occurrence of secondary metabolites (poliphenols, sphagnum acid) and specyfic hydrocarbons and proteins, decomposition of *Sphagnum* moss tissues is very slow (Verhoeven and Liefveld, 1997; Turetsky *et al*., 2008; Lang *et al*., 2009). In comparison with vascular plants, brown mosses also degrade slowly. This decrease in decomposition rate can be caused by differences in ratio of C:P between the tissues of bryophytes (both brown and *Sphagnum* moss) and vascular plants. Annual mass loss for bryophytes is estimated at 10-22%, while for vascular plants at 36-58% (Enriquez *et al*., 1993; Bayley *et al*., 2005; Moore and Basiliko, 2006; Bragazza *et al*., 2007). From the biomass of more easily dagradable vascular plants highly decomposed peats are formed, characterized by lower amounts of total organic matter and higher humic substances content. However, humic substances extracted from highly degraded acidic peats comprise mostly aliphatic hydrocarbons and heterocyclic rings, while humic substances from poorly decomposed, less acidic peats consist rather of aromatic compounds (Bambalov, 2000). The same relation was observed during this study – highly acidic peats were characterised by low $E_{4/6}$ ratio, which signifies the domination of aromatic structures in humic substances. In highly decomposed peats $E_{4/6}$ ratio was significantly higher. This observation can be explained by the fact that low pH values decrease decomposition rates and make lignin structures retain unbroken. Lignin is often viewed as a precursor in the synthesis of humic acids (Van Bergen, 1998).

As far as peat lipids are concerned, redundancy analyses showed that non-hydrolysable lipids are well preserved in poorly decomposed, highly acidic peats, such as moss and herbaceous peats studied here. In case of moss peats, high non-hydrolysable lipid content is also a result of the fact that in the lipid profile of *Sphagnum* moss tissuses prevail steroids, mostly sterols (Baas *et al*., 2000).

Summarizing, it can be stated that according to multidimensional analyses, pH values of studied peats depend mainly on habitat conditions under which the particular layers were formed. Decomposition degree is strongly influenced by floristic composition of peats. Studied geochemical features of peats are interrelated, however a main pattern of these relations can be distinguish. The amount of humic substances, both humic and fulvic acids, depends on decomposition degree of peats. Still, their aromaticity is rather under influence of pH values. The content of non-hydrolysable lipids depends on the possibility of their preservation and is connected mainly with pH values of peats. Total amount of organic matter in peats results both from pH values and degree of decomposition.

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