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DIVERSITY OF THE SOIL COVER IN THE NATURAL *TILIO-CARPINETUM STACHYETOSUM* IN THE BIAŁOWIEŻA FOREST

K. Biały

Department of Soil Science, Nicholas Copernicus University, Toruń
Gagarina 9, 87-100 Toruń, Poland

A b s t r a c t. Natural variability of pseudogley forest soils in the Białowieża National Park was characterised on the basis of five soil exposures. Two of them were located in a water-logged site, one in a mound one in a patch with dominance of deciduous trees, and one in a spruce biogrup. It was found that pseudogley soils of a natural moist deciduous forest show additional differentiation in the form of characteristic micromosaics. There is a pronounced impact of the species structure in a treestand, uprooted trees and hoofed mammals on the properties of the soil cover. Changes resulting from the above biotic factors were observed in all the analysed physical, physico-chemical and chemical soil parameters.

K e y w o r d s: soil cover, the Białowieża forest, soil properties.

INTRODUCTION

A characteristic feature of natural forest ecosystems is their spatial variability reflected in the wide diversity of soil cover and flora. Generally, certain types and subtypes of soils correspond to certain types of forest phytocenoses, contours of soil units, forming a soil-plant mosaic system, specific for a given forest complex. An example of this kind is a forest structure of the Białowieża Forest, the only vast forest complex still existing in the Central European Lowland, practically not affected by human activity. The vegetation-soil relationship there is very clear and fairly explicit. That has been demonstrated by a number of pedological [1,4], phytosociological [5] and ecological [2,3] studies. The most important part in the development of the soil cover properties in the Białowieża Forest is played by multispecies deciduous tree-stands with a diverse horizontal and vertical structure, and in some habitats also by uprooted trees and large herbivorous mammals, mainly red deer and wild boars. That is why besides the contours of the soil subtypes reflecting diversity of mineral deposits, additional differentiation of soil morphology and properties is commonly observed within one soil subtype in the form of irregular soil-plant micromosaics. This coinciding additional differentiation is particularly clear in the wet deciduous forest (*Tilio-Carpinetum stachyetosum*) developed on pseudogley soils. Morphological heterogeneity of morphology and properties is a specific feature of those soils, no longer found in the managed ecosystems. It is also the evidence of their natural conditions. The main objective of this paper is to describe the properties of these soils.

OBJECT OF THE STUDY

Natural variability of pseudogley soils in the Białowieża National Park was described using an example of a study area located in the section 370D (Fig. 1). It represents a typical fragment of a multispecies moist forest (*Tilio-Carpinetum stachyetosum*) in which there are typical moist deciduous forest species, such as hornbeam, oak, or linden, but also coniferous species - spruce, and marshy forest species - alder and ash. Another feature distinguishing that particular ecosystem from other forest ecosystems of the Park is the common occurrence of uprooted trees, mainly spruce and hornbeam, and the presence of highly characteristic flat shallow depressions (water-logged spots) with seasonally stagnating rainwater. They are often used by red deer and wild boars for mud bathing.

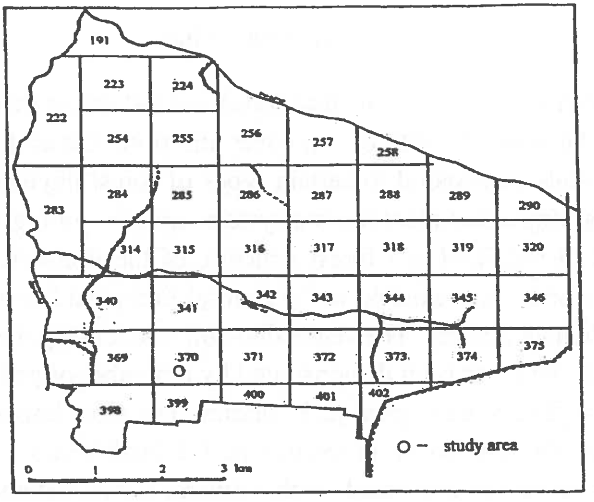
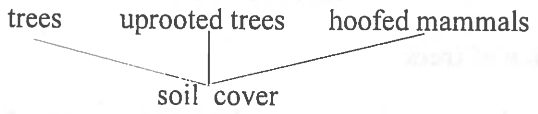


Fig. 1. Location of the study area.

BIOTIC FACTORS AFFECTING THE PROPERTIES OF PSEUDOGLEY SOILS

Basic biotic factors affecting morphology and properties of pseudogley soils in the natural moist forest are: multispecies arborescent vegetation, uprooted trees and hoofed mammals. Those relationships are presented in the following diagram:



Among arborescent vegetation, edificators are the most important in this ecosystem, among others: spruce and ash. The spruce presence impinges on the formation of organic horizon. It also influences decay rate of the organic matter accumulated in it. Whereas, the ash-part regulates water conditions in excessively water-logged sites. An important soil forming factor are uprooted trees and the remaining perturbations with their characteristically shaped pits and mounds, which not only disturb continuity of the soil cover but also initiate new ecological and pedogenic processes, decisive for the functioning of the whole ecosystem. They form a characteristic micro-relief of the forest floor, which is the evidence of its natural character. Uprooted spruce with extensive, flat roots that tear up surface horizons of the pseudogley soils exposing scarcely permeable clay with perio-dically stagnating rainwater, are of special importance. Those spots are often used by hoofed mammals for mud bathing. Animal activity consists in systematic mixing of the exposed clay with plant litter and thus forming a humus horizon of considerable thickness.

METHODS

The present studies were carried out in a selected and marked area of 20 x 10 m. Tree distribution and the contours of water-logged spots were mapped by the aqua grid method and tape measurements. Soil cover properties and its spatial diversity were characterised on the basis of five soil exposures. Two of them were located in a water-logged spot, one in a mound, one in a patch with dominance of deciduous trees, and one in a spruce biogroup. Basic properties of the soil samples taken from particular genetic horizons were assessed by the methods commonly used in soil science:

- actual moisture and volume density by the drying and weighing method,
- soil texture by the areometric method with segregation of sand fractions on sieves,

- C_{org}. content in the samples from the organic horizon by the Altens method, and from the humus horizon by the Tiurin's method,
- N total content by the Kjeldahl's method,
- pH by the potentiometric method in H_2O and KCl solutions,
- $CaCO_3$ content by the Scheibler's method.

RESULTS OF STUDY

Distribution of trees

One of the characteristic features of the Białowieża moist forest is the species diversity of the arborescent formation. Another feature is a relatively high percentage of places devoid of trees. Those are shallow water-logged microdepressions, in which development of arborescent vegetation is hampered by periodical stagnation of rainwater as well as intensive activity of red deer and wild boars that frequently tread and mix (rooting, mud bathing) the plastic soil surface horizon (Fig. 2). In the studied fragment, the most numerous is hornbeam. There is a small biogroup of spruce, and in the lower layer of the tree-stand, there are scattered specimens of young linden. The tree-stand consists of many layers. Deciduous species

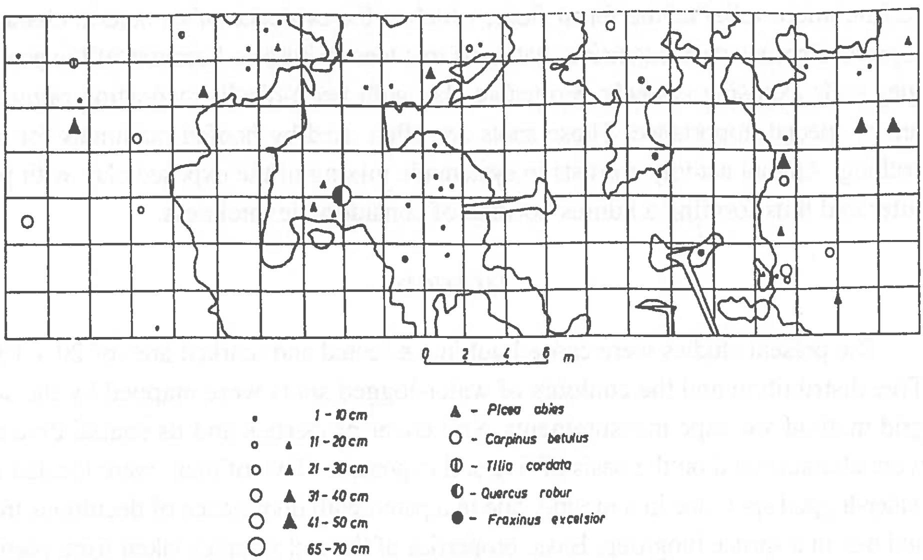


Fig. 2. Tree distribution in the study area.

show a good re-growth rate, especially hornbeam, and at the margins of the water-logged spots also ash, characteristic of marshy forests (Fig. 3). Only few specimens grow in the undergrowth layer. Most deciduous seedlings are eaten by red deer.

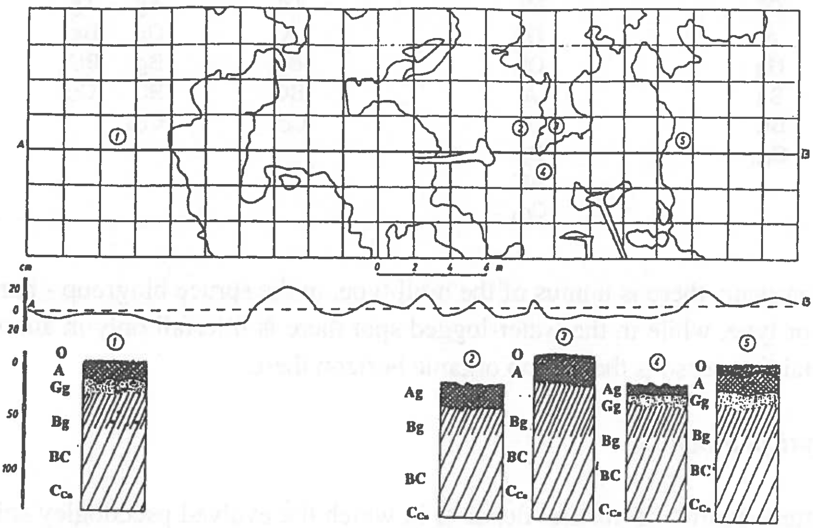


Fig. 3. Distribution of water-logged spots and soil exposures in the study area.

Soil properties

Morphological diversity

The contour of pseudogley soils under study is not morphologically homogeneous. A considerable diversity is found in the top part of the soil profiles under study (Table 1). A model sequence of genetic horizons, characteristic of that type soils can only be seen in the exposure located in the patch where deciduous trees dominate. In the remaining profiles, there is clear evidence of the impact of up-rooted trees (lack of gley horizon), of the activity of large herbivores (no organic horizons) and of the spruce activity (development of humus of the moor type). In places, where uprooted trees tore away humus and gley horizons, a secondary humus horizon has evolved, 2-3 times as thick as the former one, with no gley horizon underneath or with only its initial stage (Fig. 3). The lack of a gley horizon may result in an erroneous classification of these soils, particularly if the diagnosis is based on one randomly localised soil exposure. Considerable differences are also found in the structure of the organic horizon. In the patch where deciduous

Table 1. Diversity of genetic horizons in the pseudogley soil evolved in a patch of moist deciduous forest

Dominance of deciduous trees	Dominance of spruce	Mound	Water-logged spot	
Ol	Ol	Ol	Ag	Ag
A	Of	A	Gg	Bg
Gg	Oh	Bg	Bg	BC
Bg	A	BC	BC	C_{Ca}
BC	Gg	C_{Ca}	C_{Ca}	
C_{Ca}	Bg			
	BC			
	C_{Ca}			

trees dominate, there is humus of the mull type, in the spruce biogroup - humus of the moor type, while in the water-logged spot there is litterfall only in autumn. In the remaining seasons there is no organic horizon there.

Physical properties

Natural duality of mineral deposits in which the evolved pseudogley soils had been disturbed in places by uprooted trees and hoofed mammals, shows shallow cover loam partly mixed with the underlying clays. As a result, sandy loam which used to be the top soil part, had been enriched with <0.02 mm particles in places; since it became more compact (Table 2).

Partial mix of mineral matter resulted in the differentiation of water-air conditions in the surface horizons. As shown in the diagrams, the most favourable proportions of the three soil phases are found in mounds under spruce canopy, and the least favourable in water-logged spots (Fig. 4). There, immediately after rainfall, the soil pores in the humus horizon are completely filled with water. Water conditions in the pseudogley soils are modified by the luxuriant spruce crowns, which retain about 70% of rainfall.

Chemical properties

Basic chemical properties of the micro-mosaics distinguished in the pseudogley soils have been listed in Table 3. The above results show some chemical properties characteristic only for the surface zone of the soil profiles. That is evident particularly in the humus horizon with reference to organic matter content that is more than twice higher than in other exposures of the horizon A in the

Table 2. Texture of pseudogley soils

Horizon	Thickness (cm)	>1.0	1.0-0.5	0.5-0.25	0.25-0.1	0.1-0.05	0.05-0.02	0.02-0.005	0.005-0.002	<0.002
Fragment with dominance of deciduous trees										
A	0-10	0.1	6.0	15.8	31.8	9.0	7.0	11.0	6.0	12.0
Gg	10-22	2.0	10.4	16.1	31	8.5	6.5	10.0	5.5	11.5
Bg	22-55	0.7	3.8	7.4	9.5	3.5	4.0	9.5	13.0	49.3
BC	55-94	-	0.5	1.0	3.7	7.0	7.0	14.3	18.5	48.0
CCa	94-180	1.3	1.7	4.1	10.4	9.5	10.5	18.0	18.0	27.7
Fragment with dominance of spruce										
A	0-14	0	5.5	13.2	26.8	10.5	10.5	13.0	8.0	12.5
Gg	14-24	0.7	8.4	13.9	25.7	8.0	10.0	12.0	9.0	13.0
Bg	24-56	0.4	2.4	5.2	10.0	4.5	6.5	11.8	12.5	47.1
BC	56-105	1.5	4.6	9.8	23.7	8.0	12.0	4.0	5.5	32.4
CCa	105-180	2.9	2.9	7.8	18.4	14.0	11.0	12.0	10.0	23.9
Water-logged spot										
A	0-12	0	6.0	10.3	17.0	6.5	3.5	17.0	11.0	28.7
Gg	12-21	1.8	8.9	13.6	23.8	7.5	8.5	11.5	9.5	16.7
Bg	21-65	2.3	3.0	7.1	12.7	8.0	8.0	10.0	10.5	40.7
BC	65-95	0.2	1.0	2.8	4.7	7.5	7.5	14.0	17.0	42.5
CCa	95-180	3.1	2.0	6.1	14.5	10.5	10.5	11.5	13.5	29.5

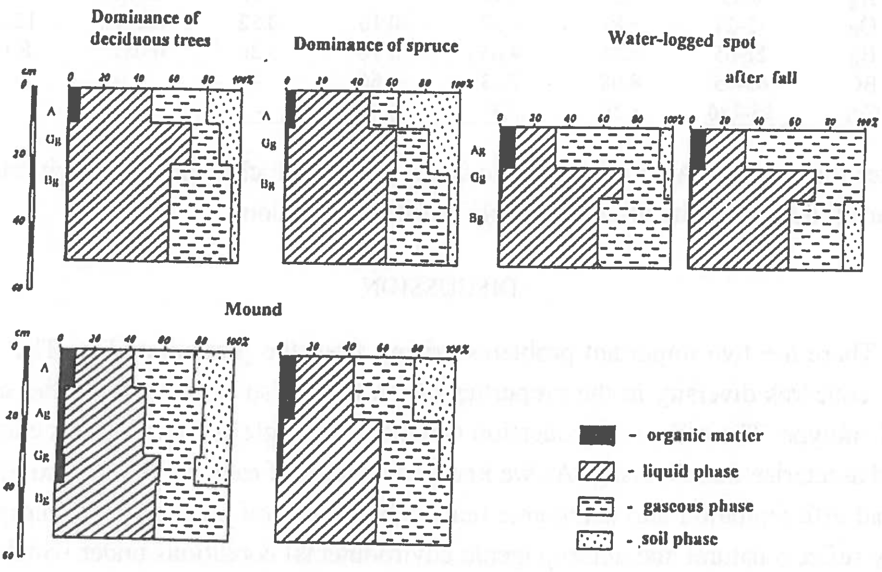


Fig. 4. Distribution of phases in the soil profiles.

Table 3. Some chemical properties of the pseudogley soils

Horizon	Thickness (cm)	pH H_2O	pH KCl	$CaCO_3$	Corg.	Ntot.	C/N
				(%)			
Dominance of deciduous trees							
Ol	2-2	4.36	3.77	-	42.23	1.141	37.0
OlA	1-0	4.19	3.22	-	20.24	1.208	16.8
A	0-10	4.32	3.33	-	3.73	0.188	19.8
Gg	10-22	5.41	4.19	0.15	0.23	0.017	13.5
Bg	22-55	5.27	3.68	0.20	0.31	0.030	10.3
BC	55-94	8.02	7.21	9.87	-	-	-
C_{Ca}	94-180	8.18	7.43	17.65	-	-	-
Dominance of spruce							
Ol	7-6	4.67	3.98	-	41.88	1.101	38.0
Of	6-3	4.27	3.46	-	30.19	1.197	25.2
Oh	3-0	4.22	3.38	-	25.53	1.203	21.2
A	0-14	4.44	3.47	-	2.71	0.142	19.1
Gg	14-24	4.73	3.74	0.16	0.60	0.042	14.3
Bg	24-56	5.12	3.62	0.18	0.32	0.041	7.8
BC	56-105	8.18	7.30	6.99	-	-	-
C_{Ca}	105-180	8.29	7.23	13.12	-	-	-
Water-logged spot							
Ag	0-12	5.37	4.73	-	7.19	0.421	17.1
Gg	12-21	5.81	4.57	0.16	0.52	0.041	12.7
Bg	21-65	6.15	4.65	0.16	0.30	0.037	8.1
BC	65-95	8.08	7.13	4.66	-	-	-
C_{Ca}	95-180	8.39	7.35	12.14	-	-	-

water-logged spot. Also the C/N ratio is the lowest, which indicates a high rate of litterfall decay in spite of unfavourable moisture conditions.

DISCUSSION

There are two important problems arising from the present studies. The first one concerns diversity in the properties of the natural soil cover within the same soil subtype. The other is the question whether one single soil exposure is enough to characterise that diversity. As we know, diagnosis of each soil cover and its internal differentiation into taxonomic units is based on soil profiles. Their morphology reflects natural and anthropogenic environmental conditions under which the soil evolved together with pedogenic processes in it. The characteristics inscribed in the profile allows to classify the soil in the right taxonomic unit and explain its origin. In managed forests where long-lasting human activity resulted in a considerable unification and standardisation of the soil covers, one profile can be a sufficient indicator characterising the properties of a given soil subtype. Generally speaking, a description of a whole soil contour is based on the properties of only one soil profile. Diagnosing and distinguishing natural forest soil contours presents an entirely different problem. As can be seen in the example of the moist forest in the Białowieża National Park, the soil cover is not homogeneous, even within one soil subtype. Considerable morphological diversity is found there in the area of only a dozen or so metres. In pseudogley soils there are not only characteristic soil profiles with a classically developed sequence of genetic horizons, but also profiles with a modified morphology or such profiles that due to their properties cannot be classified explicitly in that taxonomic unit. In the studied area such a profile were described in the water-logged spot. If the origin of the surface transformations had not been explained and the diagnosis of the whole patch of the studied moist forest had been based on that exposure only, then the soils developed in it would not have been classified as pseudogley soils but as black earths.

Differentiation of the studied pseudogley soils into characteristic micro-mosaics is limited to surface horizons only: organic (O) and the humus horizon (A). The organic horizon evolves in places grown with arborescent vegetation, while in the water-logged spots devoid of trees the organic horizon does not occur or it occurs only at the time of falling leaves. In the spruce biogroups organic matter accumulates on the surface of the mineral soil, forming humus of the moor type, while in the patches with dominant deciduous trees, there is level of humus is lower and of the mull type. That is why carbon content in the humus horizon (Fig. 5)

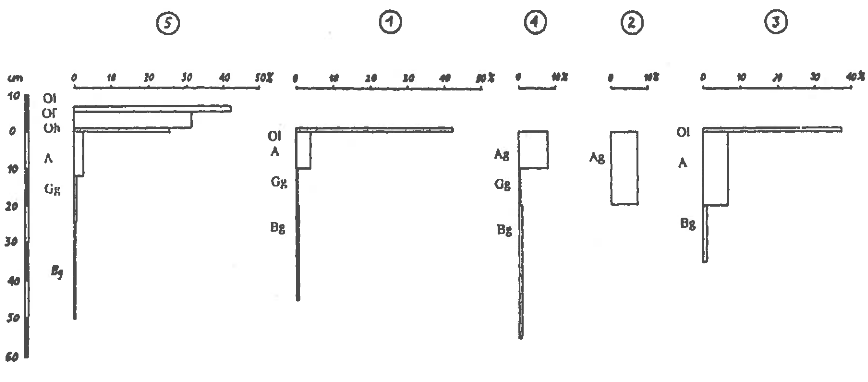


Fig. 5. Distribution of organic carbon in the soil profiles.

shows considerable spatial variation over the whole studied area (from 2.71% to 7.19%). Surface horizons differ also in their pH. In the water-logged spots, pH of the humus horizon is by 1 or 1.5 units higher than the pH in the corresponding horizon in the spruce biogroup or in the patch with dominant deciduous trees. A common feature of all the studied exposures is a wide range of pH values, which is certainly favourable for their buffer properties.

CONCLUSIONS

1. Pseudogley soils of a natural moist deciduous forest show additional differentiation in the form of characteristic micromosaics.

2. There is a pronounced impact of the species structure in a treestand, uprooted trees and hoofed mammals on the properties of the soil cover.

3. Changes resulting from the above biotic factors were observed in all the analysed physical, physico-chemical and chemical soil parameters.

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