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Fabric and properties of mineral soils underlying a shallow peat mantle in Estonia

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ABSTRACT

The morphology and chemical characteristics of mineral soils underlying modern peaty (histic) and shallow peat soils (or histosols) are analyzed in pedoecological conditions of Estonia. The underlying shallow peat mantle gley soils have been formed on different geological origin (glaciolacustrine, glacial, glaciofluvial, marine) parent materials. The peat mantle overlying gley soils has accumulated in the process of landscape paludification during the post glacial period. Using the Estonian Soil Classification (ESC), the peat layer thickness of peaty soils is 10–30 cm and of shallow peat soils, 30–100 cm. The studied peaty soils may be characterized as polygenetic soils. Depending on parent material properties (calcareousness, acidity, texture) and feeding water the peaty soils are divided into two types specified by ESC as peaty gley soils and peaty podzols, and by WRB as Histic Gleysols and Histic Podzols. The mineral soils underlying peat soils may be defined as paleosols. The development of such soils has proceeded according to the chronosequence: gley soils or protosols → peaty soils → fen soils → transitional bog soils → bog soils, whereas mineral paleosols may be found under fen, transitional bog and bog soils. The peat soils studied in this research work, classified by ESC as drained shallow transitional (mesotrophic) bog soils and by WRB as Drainic Dystric Ombric Hemic Fibric Histosols, are located on the edges of bog areas and are fed mostly by mesotrophic surface seepage water. In comparative analysis of three soil groups (peaty gley soils, peaty podzols and shallow peat soils) (i) their location on the landscape, the geological origin of their parent materials and morphology of the mineral layers are characterized; (ii) the vertical distribution of organic carbon and total nitrogen contents, and different characteristics of soil acidity are analyzed, and (iii) their catenal position or associated soils are characterized. In the case of peaty soils, the three types of mineral soil profiles (eluvial, eluvio-accumulative and accumulative) which underlie the peat cover were elucidated. Under thicker peat layers, i.e. under shallow peat soils, mostly humus accumulative profiles were found. In all analyzed sites, in the course of progressive paludification (among this peatification) the peaty soils have been formed from gley soils. The formation of the peaty soil stage was followed by the fen soil stage. Depending on the feeding water, some of these soils developed in the direction of bog soils, with an intermediary transitional bog stage. Artificial drainage is of great importance in the development of peat cover, which influences first the decomposition of top layer peat.

1. Introduction

The formation of peat mantle (organic layer) on the lowest, liberated from continental ice and sea water, areas of Estonia took place during the postglacial period in the process of landscape paludification (including peatification). As the process developed, the mineral soil cover of the lowest parts of the landscape was gradually isolated by peat mantle from biological turnover and circulation of its component substances; the influence of

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meteorological features on mineral part of the soil cover weakened as well. At a certain point in time, the mineral soils were buried under the peat mantle: therefore, they may be treated as paleosols.

In this study, the morphology, geological origin, granulometric composition and some chemical characteristics of mineral soil layers located under thin (<100 cm) peat mantle are analyzed in the temperate zone of the Atlantic–continental climatic conditions. For better understanding the developmental peculiarities of the mineral soil cover, the data on formation time, position on the landscape and association with adjacent soils are presented. At the present time, the development of these buried mineral soils is controlled or influenced to a great extent by the character of the peat mantle covering them, and therefore the composition and fabric of the peat mantle and peculiarities of its modern ecological relationships with plant cover and feeding water (including artificial drainage) are also treated.

The forming of the soil cover on higher Estonian (Upland Estonia) areas was initiated approximately 11–12,500 years ago, but on lower areas (Lowland Estonia) much later (7–8000 years ago; Raukas, 1995). The peatification of mineral gley soils started very soon after their liberation from the ice and sea water. The forming of high bog peats began later, 6–7000 years ago.

The dominating parent materials of mineral soils underlying a shallow peat mantle are glaciolacustrine, glacial, glaciofluvial and marine deposits, with variegated texture and fabric. It appears that the research on the development of soil cover under the peat mantle, from the aspect of soil science, has been modest.

2. Material and methods

2.1. Material

For the research work, data from the soil survey 'BioSoil' conducted under the framework of EC regulation Forest Focus were used. Data regarding the humus status characteristics from the database 'Pedon' as baselines levels in the evaluation of buried and paleosols development stages in comparison with modern normally developed soils were used as Supplemental Data.

The distribution of BioSoil research areas (RA) by Estonian counties is given in Fig. 1; their complete list (numbers and names), grouping and soil species may be found in Table 1. The general and pedoecological characterization of separated soil groups is shown in Tables 2 and 3. Soil names of RAs are given by Estonian Soil Classification (ESC) and the World Reference Base for Soil Resources (WRB) with their codes (Table 1), but soil texture in the same table only by WRB (Kõlli et al., 2008; IUSS…, 2014). Names of soil groups are given in Table 2 by ESC and in Table 3 by WRB; group II is subdivided by certain characteristics into two subgroups (IIa and IIb). Soils of group IIa have been formed in much more fertile edaphological conditions as compared with soil group IIb (Table 3). In the process, previously published research on soil genesis (Reintam, 1997) as well as geological, telmatological and other works conducted in Estonia (Valk, 1988; Orru, 1995; Raukas, 1995; Raukas, Teedumäe, 1997) were used.

Table 1
Research areas (RA), their distribution by counties, soil species by ESC and WRB, and altitude above sea level.

Groups[a] of RA	No of RA	Site of RA	County	Location on landscape		Code by ESC[d]	Code by WRB	Texture by WRB
				AASL[b], m	Group[c]			
I (5)	43	Mäetaguse	Ida-Viru	48	Nll	S_{2-3}''	HS-hm/sa/om/dy/dr	LS/SL
	59	Käru	Lääne-Viru	96.5	Nul	S_2''	HS-hm/om/dy/dr	SiL
	88	Kaavere	Jõgeva	76.5	Sul	S_{1-2}''	HS-hm/fi/om/dy/dr	L
	117	Sandra	Viljandi	21.5	Sll	S_{1-2}'''	HS-hm/fi/om/dy/dr	S
	121	Meleski	Viljandi	34	Sll	S_2''	HS-hm/om/dy/dr	LS
IIa (3)	29	Mustanina	Ida-Viru	28	Nll	Go1	GL-hi/rd/cc/eu-sl/dr	SiL/SiCL
	64	Käina	Hiiu	15.5	Nll	Go1	GL-hi/rd/eu-dr	S/SCL
	195	Rassiku	Jõgeva	54.5	Nul	Go1	GL-hi/rd/ca-lo/dr	L/SL
IIb (3)	27	Kalina	Ida-Viru	70.5	Sul	GI1	GL-hi/rd/dy-lu/dr	LS/S/LS/CL
	102	Rääka	Viljandi	36.5	Sll	GI1	GL-hi/rd/sp/dy-ar/dr	S/S
	188	Loone	Rapla	57.5	Nul	GI1	GL-hi/rd/dy-ar/lu/dr	S/S
III (7)	7	Vahastu	Harju	46.5	Nll	LG1	PZ-hi/ab-ar/dr	S/S
	26	Aruvälja	Ida-Viru	54	Nul	LG1	PZ-hi/ab-ar/dr	S/LS/S
	63	Remniku	Ida-Viru	32	Nll	LG1	PZ-hi/ab-ar/dr	S/S
	109	Aula-Vintri	Saare	32	Nll	LG1	PZ-hi/ab-ar/dr	S/S
	130	Kanaküla	Pärnu	32	Sll	LG1	PZ-hi/ab-ar/dr	S/S
	154	Taagepera	Valga	105	Sul	LG1	PZ-hi/ab-ar/dr	S/LS
	159	Mustjõe	Põlva	90	Sul	LG1n	PZ-hi/ab/os-lo/dr	SL/SiL/L

[a] Characterization of soil groups is given in Tables 2 and 3.
[b] AASL – altitude above sea level.
[c] Classifying of RA-s by their location on landscape: N – North Estonia, S – South Estonia, ll – lowland, ul – upland.
[d] Soil codes by ESC: S″ – thin (S‴ – thick) transitional bog soils, where the lower indexes indicate peat decomposition degrees (1 – slightly, 2 – moderately and 3 – well), Go1 – saturated peaty soils, GI1 – unsaturated peaty soils and LG1 – peaty podzols.

Table 2
Research areas' groups, their names by ESC and general characterization.

Soil group		No of RA	Position on landscape and type of feeding water	Composition of tree layer[b]
No	Name[a]			
I	Transitional bog soils	43, 59, 88, 117, 121	Fed mostly on rainfall and mesotrophic seepage surface water; mixotrophic bog plains edges	Pn7-8Bt2(Pc)
IIa	Peaty gley soils	29, 64, 195	Depressions bottoms (lowest areas) on landscape and transitional areas between mineral and organic soil covers; fed by minerotrophic surface water	Bt5-6Pc1-4Pn1-3
IIb		27, 102, 188		
III	Peaty podzols	7, 26, 63, 109, 130, 154, 159	Depressions on poor sandy wet areas and between beach ridges; fed by minerotrophic acid surface water	Pn10(Bt)

[a] By ESC.
[b] Tree species: Bt – Betula, Pn – Pinus, and Pc – Picea (number following the tree – share of ten).

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