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Soils in an agricultural landscape of Jokioinen, south-western Finland

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Eleven pedons in an agricultural landscape at elevations 80–130 m above sea level in Jokioinen, south-western Finland were investigated and classified according to Soil Taxonomy, the FAO-Unesco system (FAO), and the World Reference Base for Soil Resources system (WRB). The soils were related to geomorphology of the landscape which is characterized by clayey fields and forested bedrock high areas covered with glacial till. A Spodosol/Podzol was found in a coarse-sandy soil in an esker while the sandy loam in a bedrock high area soils did not have an E horizon. A man-made mollic epipedon was found in a cultivated soil which had a sandy plow layer while clayey plow layers were ochric epipedons. Cambic horizons, identified by structure and redox concentrations, were common in cultivated soils. In a heavy clay soil, small slickensides and wedge-shaped aggregates, i.e., vertic characteristics, were found. Histosols occurred in local topographic depressions irrespective of the absolute elevation. According to the three classification systems, the following catenas are recognized: Haplocryods – Dystro/Eutrocryepts –Haplocryolls – Cryaquepts – Cryosaprists (Soil Taxonomy), Podzols – Regosols – Cambisols – Histosols (FAO–Unesco), and Podzols – Cambisols – Phaeozems – Gleysols – Histosols (WRB).

Key words: soil formation, artificial drainage, structure, redoximorphic features, vertic characteristics, catenas, Soil Taxonomy, FAO-Unesco System, World Reference Base for Soil Resources

Introduction

The landscape in Jokioinen in south-western Finland is characterized by clayey fields which are surrounded by forested bedrock high areas, covered mostly by glacial till, and by eskers consisting of coarse sandy glacial outwash. In addition to these mineral materials, there are peat formations in the depressions of the landscape.

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Glacial till covers 29% of the area, clayey soils 53%, organic soils 5%, silt and sand 5%, rocky areas 7% and rivers and lakes about 1% of the area (Urvas 1997). The most important river of the region is River Loimijoki. It has carved itself through the clayey lacustrine deposits which are sometimes as deep as 30 m (Rainio 1997). Intensive crop production takes place in southern and western Finland in similar landscapes.

The present landscape was formed by the Weichselian glaciation and the evolutionary stages of the Baltic Sea. At Jokioinen, the sea level during the ice melt period about 9 500 years ago was at 135–140 m above the present sea level (Rainio 1997). The fine-grained sediments in the region were deposited in the Yoldia sea (10 200–9 500 BP) which covered practically the whole landscape. Owing to isostatic rebound, even the lowest areas of Jokioinen have been above sea level at least 8000 years. The soils have thus been subject to pedogenic processes much longer than in a landscape in Helsinki where most agricultural land has emerged from the sea less than 2000 years ago (Mokma et al. 2000).

A vast number of agricultural experiments have been carried out in the study area, due to fact that Agricultural Research Centre of Finland is situated in Jokioinen. Maps of quaternary deposits of the region have been published, but the soils have not been investigated for pedogenic features. The purpose of this study was to investigate the pedogenic properties of typical soils of Jokioinen and relate their occurrence to the geomorphic setting and development of the landscape.

Material and methods

Out of the 11 pedons studied, eight (03...09, 11) are in agricultural use. They have mostly been cultivated since the 17th century. First they were drained with open ditches and starting about 70 years ago they were pipe-drained. Two pedons (01, 02) are forested and one (10), within the floodplain of River Loimijoki, has been cropped but has been abandoned for some decades. The elevation varies from 80 to 130 m above sea level. The studied pedons are within 60°48' – 60°54'N and 23°27'- 23°32'E and their accurate coordinates are given according to the Finnish KKJ system (basic coordinates) in Table 1. Profiles 02, 05...10 are within 1 km^2 (Fig. 1) while the rest are 3–10 km North or North-east of them. The cultivated soils represent the important experimental fields of Agricultural Research Centre of Finland and the other three soils are representative for the forested and floodplain areas. Out of the cultivated soils, five (04...08) are clayey throughout the profile. Three (04, 07, 08) of the clayey pedons are similar to pedons 05 and 06, and therefore their data are not presented. Pedon 07 is slightly different from the other four by having less than 60 percent clay in the profile (45–65% vs. 65–95%).

The pedons were described (Table 1) and sampled in June 1997 and August 1999 according to the methods of Soil Survey Staff (1993). Pedon 05 was not sampled. Particle size distribution was determined by the pipette method after digestion with hydrogen peroxide. Organic C was determined using the Leco dry combustion apparatus (Laboratory Equipment Corporation, St. Joseph, MI). Soil pH was measured in water (soil:water 1:2.5 by volume). Base saturation, on the basis of the sum of exchangeable Ca, Mg, Na, K and H, was determined by ammonium acetate extraction (pH 7.0). In two pedons (01 and 02), Fe and Al were extracted with 0.5 M ammonium oxalate (pH 3.0) to check for the presence of spodic horizons. Phosphorus (P) was extracted with 1% citric acid to identify anthropogenic accumulation of P in the soil (Soil Survey Staff 1975, FAO 1988). The pedons were classified according to Soil Taxonomy (Soil Survey Staff 1998), the FAO-Unesco system (FAO 1988) and the World Reference Base for Soil Resources system (FAO 1998) assuming that the pedons have a cryic temperature regime (Yli-Halla and Mokma 1998).

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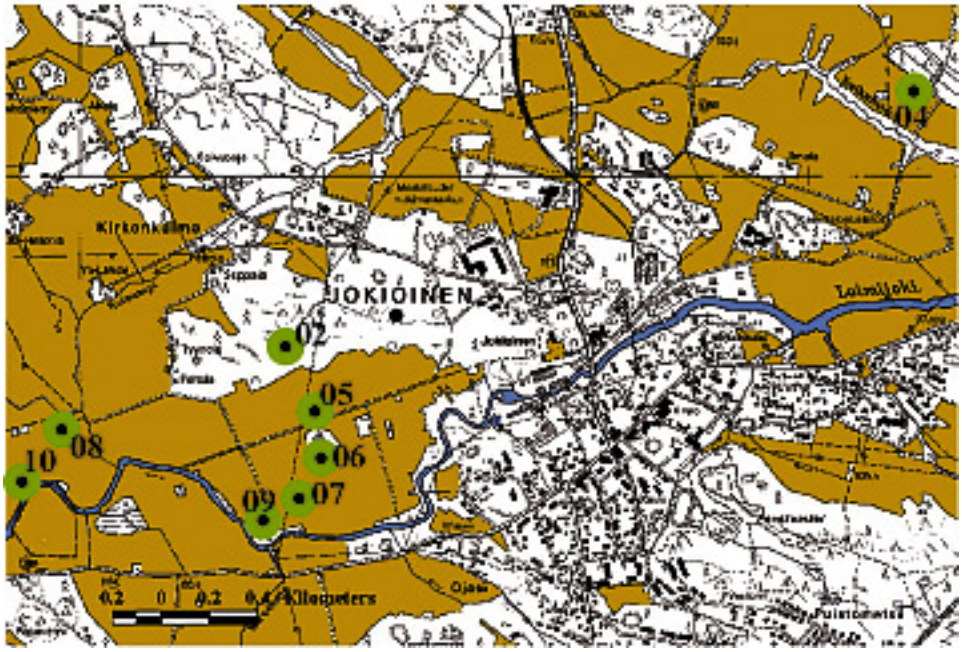

Fig. 1. Location of eight of the investigated pedons. The pedons 01, 03 and 11 are north of the area in the map. ©Maanmittauslaitos /National Land Survey of Finland, permission number 526/MYY/00.

Results and discussion

Coarse and medium textured soils

Pedon 01 represents the highest part (elevation 130 m) of the esker Kukonharju, which is the largest esker of the area. The mineral material (<2 mm) is dominated by coarse sand while the clay and silt, 10% or less (Table 2), had been sorted out. Therefore, these materials are preferred for construction materials, and mining of sand and gravel is common in this esker. In the horizons below 35 cm more than 60% of the mass consist of material larger than 1 cm. As a result of the vegetation (Scotch pine, lichens, some mosses and grasses) the profile has an O horizon. The soil has a continuous thin albic horizon (7.5YR 4/1) (Table 1). The low pH, >0.6% organic C, the color (7.5YR 4/4) of the Bs1 horizon and the presence of an albic horizon are evidence of the presence of spodic materials, which is further confirmed by the accumulation of oxalate-extractable Al and Fe (0.55%) in the Bs1 horizon and depletion of these elements (0.07%) in the E horizon. The soil is a Haplocryod (Soil Survey Staff 1998) and a Podzol (FAO 1988, 1998) (Table 3).

Pedon 02, at the elevation of 110 m, contained many stones, often larger than 15 cm in diameter, preventing digging a pit deeper than 70 cm by shovel. Differing from profile 01, this profile contained as much as 33–40% of silt in the fine earth fraction even though sand was the dominant particle size. The particle size distribution shows that the soil has not been subject to intensive sorting. This forested area is more moist than the Kukonharju esker (pedon 01) and it is vegetated by spruce, mosses and grasses. Despite the brown color (7.5YR 4/3 and 10YR 4/4), low pH and sufficient contents of Fe, Al and C, the Bw horizon doesn't meet the criteria

Table 1. Description of soil profiles from the Jokioinen area.

Horizon	Depth, cm	Color matrix	Color mottles	Texture	Structure
Jokioinen 01, x=2474380, y=6747420					
Oa	0–7	7.5YR 3/2		sapric	
E	7–10	7.5YR 4/1		lfs	1f sbk
Bs1	10–35	7.5YR 4/4		lfs	1m sbk
2Bs2	35–64	7.5YR 4/6		vgrs	0sg
2BC	64–75	10YR 4/4		ex cob s	0sg
2C	75–90	10YR 4/4		ex gr s	0sg
Jokioinen 02, x=2470930, y=6744340					
Ah	0–15	7.5YR 3/2		l	
Bw1	15–25	7.5YR 4/3		sl	
Bw2	25–45	10YR 4/4		sl	
Bw3	45–55	10YR 4/6		sl	
C	55–70	2.5Y 5/4		sl	
Jokioinen 03, x=2471520, y=6748730					
Ap	0–27	10YR 4/3, 10YR 5/3 dry		sil	1c pl
Bw1	27–36	10YR 4/6	f2f 10YR 6/8	sil	1vc pl
Bw2	36–62	2.5Y 5/3	m3f 2.5Y 5/4		1vc pl/1m sbk
			c3p 10YR 4/4–5/8		
			c2p 2.5YR 6/2		
C1	62–72	10YR 5/3	c2p 7.5YR 3 /4	sic	1f pl/2f abk
2C2	72–80	2.5Y 5/4	c2p 10YR 5/6	sil [1)]	1m pl
3C3	80–89	2.5Y 4/1	m2p 5YR 3/3	c	1f pl/2f abk
			f1p 2.5YR 4/6		
4C4	89–123	10YR 4/2, 10YR 5/3	c2f 10YR 5/2		
		and 2.5Y 6/4	c2d 10YR 4/6		
				sl [1)]	1m pl
5C5	123–132	2.5Y 4/1	m2p 7.5YR 3 /4	c	1m pl/2m abk
6C6	132–215	10YR 6/4	c1d 10YR 6/1	ls [2)]	1m pl
			c1d 10YR 5/6		
Jokioinen 05, x=2470960, y=6743980					
Ap	0–22	10YR 4/2, 10YR 7/3 dry		c	2m sbk
Bw1	22–40	10YR 4/2		c	3c pr/3m abk [4)]
Bw2	40–72	10YR 3/2	c1f 10YR 3/3	c [3)]	2m abk [4)]
Bw3	72–112	10YR 3/2	c2f 10YR 3/3	c	1m abk [4)]
Cg	112–150	10YR 4/1	m2p 10YR 5/4	c	
Jokioinen 06, x=2471090, y=6743850					
Ap	0–23	10YR 4/2, 10YR 6/3 dry	f1f 10YR 4/3	c	2f gr [5)]
					1m abk [5)]
AB	23–45	10YR 4/1	m3f 10YR 4/1	c	1f abk
			c2f 10YR 4/4		
Bg1	45–60	10YR 4/2	c2p 7.5YR 4/4	c	2m abk
			m3f 10YR 5/1 [7)]		
			c1f 10YR 2/2 [8)]		
Bg2	60–91	10YR 4/2	m2p 7.5YR 4/4	c [6)]	1c pr/2m abk
			m3f 10YR 5/1 [1)]		
			c1f 10YR 2/2 [8)]		
BC	91–142	10YR 4/2	m2p 7.5YR 4/4	c [6)]	2c pr/2m abk
			m3f 10YR 5/1 [7)]		
			c1f 10YR 2/2 [8)]		

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Horizon	Depth, cm	Color matrix	Color mottles	Texture	Structure
Cg	142–169	10YR 4/2	m3f 10YR 5/1 [7)] c3p 7.5YR 4/6 c1f 10YR 2/2 [8)]	c [6)]	2m pl/2m abk
Jokioinen 09, x=2470840, y=6743530					
Ap	0–30	10YR 3/2, 10YR 5/2 dry		sl	1c sbk
Bw1	30–40	10YR 5/3	c3p 7.5YR 4/6	sl	1m sbk
Bw2	40–45	10YR 5/3	f2p 7.5YR 4/6	sl	1m sbk
2Bw3	45–70	10YR 4/2	m2p 7.5YR 5/6 c2f 10YR 5/2	sic	2c sbk/2f-m abk
2BC	70–100	10YR 4/2	m2p 7.5YR 5/6 m3p 5Y 5/1 [7)]	c	2c sbk/2f abk
2Cg	100–150	10YR 4/2	c2f 10YR 3/4 m3p 2.5Y 5/1 [7)]		2vc pr/2m abk
Jokioinen 10, x=2469790, y=6743740					
Ap	0–15	10YR 3/2, 10YR 6/1 dry		c	3f gr
Bg	15–39	10YR 4/2	c1p 7.5YR 3/3	c	2f sbk/2f abk
Oab1	39–55	10YR 3/1	m3p 5YR 3 /4[7)]	sapric	2m pr/2m abk
Oab2	55–80	10YR 3/2 → 2/1 [9)]	c3p 7.5YR 3 /4 [7)]	sapric	2c pr/2c pl
Oab3	80–110	10YR 3/3 → 3/2 [9)]		sapric	1c pr/2c pl
Cg1	110–120	10YR 3/2		c	2c pl
Cg2	120–128	5Y 4/1		c [10)]	0m
Jokioinen 11, x=2473730, y=6754660					
Oap	0–35	5YR 2.5/2, 7.5YR 4/2 dry		sapric	1c sbk/2f sbk
Oa1	35–59	5YR 2.5/1		sapric	3c sbk/2f sbk
Oa2	59–80	2.5Y 2.5/1		sapric	2m pl
Oa3	80–104	10YR 3/2		sapric	1vc pl/1vc abk
2Cg	104–135	5Y 5/1		c	0m

[1)] thin (<2 mm) strata of vfsl and sil
[2)] thin (<2 mm) strata of vfsl
[3)] at 44 cm, thin (<2 mm) strata of si
[4)] slickensides/ pressure faces at 22–40, 60 and 100–110 cm
[5)] granular at 0–7 cm, blocky at 7–23 cm
[6)] thin (<2 mm) strata of si
[7)] continuous coatings on ped faces
[8)] Mn oxide nodules
[9)] The lighter color changes into the darker one within 1 min of exposure to air.
[10)] Many dead fine roots and remnants of grassy plants

Abbreviations:
Texture: c=clay, sic=silty clay, l=loam, sil=silt loam, sl=sandy loam, vfsl=very fine sandy loam, vfsil very fine silt loam, ls=loamy sand, sl=sandy loam, lfs=loamy fine sand, vgrs=very gravelly sand, ex cob s=extremely cobbely sand, ex gr s=extremely gravelly sand
Mottles: f=few (<2% of surface), c=common (2–20%), m=many (>20%), 1=fine (<5 mm), 2=medium (5–15 mm), 3=coarse (>15 mm), f=faint, d=distinct, p=prominent
Structure: 0=structureless, 1=weak, 2=medium, 3=strong, vf=very fine, f=fine, m=medium, c=coarse, gr=granular, sbk=subangular blocky, abk=angular blocky, pl=platy, pr=prismatic, m=massive, sg=single grain. Slash between the structural attributes means that the coarser aggregates part to the finer ones.

Table 2. Selected physical and chemical properties of pedons in Jokioinen. P was extracted with 1% citric acid. Clay stands for particles <0.002 mm, silt for 0.002–0.06 mm and sand for 0.06–2 mm. Index stands for 0.5 x Fe + Al, extracted with acid oxalate.

Depth cm	pH (H_2O)	Org. C %	Clay %	Silt %	Sand %	CEC pH 7.0 cmol kg^{-1}	Base saturation, %	>2 mm %	Index %
Jokioinen 01									
0–7	4.02	29.4							
7–10	4.00	2.0	2	9	89			2	0.07
10–35	4.96	0.82	2	8	90			14	0.55
35–64	5.34	0.30	0	6	94			89	0.28
64–75	5.38	0.29	1	8	91			82	0.33
75–90	5.66	0.14	1	3	96			81	0.21
Jokioinen 02									
0–15	4.67	5.37	8	40	52	15.8	14	0	0.55
15–25	4.85	3.14	8	38	54	11.8	10	41	0.69
25–45	5.14	1.87	6	33	61	8.1	8	54	1.10
45–55	5.31	0.83	4	32	64	5.4	10	46	0.80
55–70	5.33	0.40	4	33	63	3.2	11	57	0.44
								P mg kg^{-1}	
Jokioinen 03									
0–27	5.91	1.56	13	54	33	11.3	59	131	
27–36	6.38	0.39	4	54	42	4.08	49		
36–62	6.50	0.18	2	56	42	2.86	44		
62–72	6.76	0.35	50	43	7	20.1	82		
72–80	6.71	0.20	3	62	35	7.05	55		
80–89	6.73	0.39	63	30	7				
89–123	6.61	0.13	2	48	50				
123–132	6.29	0.47	87	7	6				
132–215	6.58	0.05	1	22	77				
Jokioinen 06									
0–23	6.09	2.67	57	32	11	24.6	74	255	
23–45	6.47	1.00	81	16	3	33.1	87	55	
45–60	6.94	0.43	73	25	2	26.9	91		
60–91	7.14	0.35	76	24	0	28.3	92		
91–142	7.13	0.30	89	11	0	31.1	93		
Jokioinen 09									
0–30	6.54	2.44	13	14	73	14.9	86	347	
30–40	6.79	0.47	8	19	73	5.11	90	75	
40–45	6.86	0.14	9	15	76	4.54	89	41	
45–70	6.95	0.23	45	42	13	24.8	92	85	
70–100	7.20	0.23	57	37	6	27.1	92	200	
100–150	7.33	0.32	69	27	4	29.2	92	213	
Jokioinen 10									
0–15	5.18	10.1	68	32	0				
15–39	5.20	10.1	68	31	1				
39–55	5.38	19.7	65	33	2				
55–80	5.65	22.6	64	32	4				
80–110	5.73	20.1	69	29	2				
110–120	5.85	11.1	76	23	1				
120–128	6.09	3.4	70	30	0				
Jokioinen 11									
0–35	5.70	25.9				138	20	277	
35–59	5.11	22.3				125	20	88	
59–80	5.11	33.2				141	21	59	
80–104	4.60	18.3				86.7	23	107	
104–135	5.20	1.7	82	14	4	29.7	45	288	

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Table 3. Classification of the investigated pedons according to Soil Taxonomy (Soil Survey Staff 1998), FAO-Unesco system (FAO 1988) and Word Reference Base for Soil Resources (WRB) system (FAO 1998).

Profile	Land use[1)]	Elevation m	Soil Taxonomy	FAO-Unesco	WRB
1 Kukonharju	f	120	Entic Haplocryod	Haplic Podzol	Haplic Podzol
2 Ojainen	f	110	Typic Dystrocryept	Dystric Regosol	Dystric Cambisol
3 Rehtijärvi	c	106	Aquic Eutrocryept	Dystric Regosol	Dystric Cambisol
4 Kotkanoja	c	100	Typic Cryaquept	Vertic Cambisol	Vertic Cambisol
5 Ojainen	c	92	Vertic Cryaquept	Vertic Cambisol	Vertic Cambisol
6 Ojainen	c	90	Typic Cryaquept	Vertic Cambisol	Vertic Cambisol
7 Ojainen	c	90	Typic Cryaquept	Vertic Cambisol	Vertic Cambisol
8 Ojainen	c	82	Typic Cryaquept	Vertic Cambisol	Vertic Cambisol
9 Ojainen	c	85	Aquic Haplocryoll	Eutric Cambisol	Haplic Phaeozem
10 Luhta	p	80	Terric Cryosaprist	Terric Histosol	Thaptohistic Gleysol
11 Kuuma	c	108	Terric Cryosaprist	Terric Histosol	Sapric Histosol

[1)] c=cultivated, p=previously cultivated, f=forested

of spodic materials. This is due to the fact that no albic horizon was present and insufficient accumulation of Fe and Al (0.69%) relative to the horizon above (0.55%) was measured. Low base saturation throughout the profile suggests that many base cations have leached. It is likely that upon further leaching of base cations an E horizon will develop and the soil will approach the Spodosol order. Currently this soil is a Dystrocryept (Soil Survey Staff 1998). In the FAO-Unesco system, criteria of a cambic horizon include, among other requirements, a minimum clay content of 8% and a minimum thickness of 15 cm. The Bw1 horizon is thus too thin to be a cambic horizon in that system, and the soil is a Regosol (FAO 1988). In the World Reference Base for Soil Resources (WRB) system, there is no textural requirement for a cambic horizon, and therefore Bw1 and Bw2 together qualify for a cambic horizon and the soil is a Cambisol (FAO 1998).

Pedon 03 (elevation 106 m) is in a small esker which for the most part consists of fine sandy loam, coarse silt and fine sand being the principal particle sizes. In addition, at 60, 80 and 120 cm, there are thin (10 cm) horizons of silty clay loam or silty clay with abrupt boundaries. The lithological discontinuities in this pedon reflect differences in velocity of water which was a function of the rate of melting of the glacial ice. The fine sandy loam has a base saturation of 44–49%, which is considerably higher than in the coarser soils 01 and 02 but much lower than in the clay-textured horizons of this soil and in the clayey soils of this study. In spite of the location in an esker above the surrounding fields, there are redox depletions (2.5Y 5/4) in the fine sandy loam above the clayey horizon, reflecting slow water movement through the clay. This soil is an Eutrocryept (Soil Survey Staff 1998), and a Cambisol (FAO 1998) but, owing to a clay content <8% in the B horizon, it is a Regosol in the FAO-Unesco system (FAO 1988).

The Soil Map of Denmark, Finland, Norway and Sweden (Rasmussen et al. 1989) and the Soil Geographic Database of Europe (European Soil Bureau 1998), following the classification of FAO (1974), both indicate that Cambisols and Podzols are the two dominant soils in this area. However, in our study Podzols were only found in sandy materials while Regosols, not recognized in the map and database mentioned above, seemed to occupy areas of non-podzolised loamy soils.

Clayey soils

The clayey lacustrine sediments dominate the cultivated land. These soils are represented by

Fig. 2. Prisms taken right below the plow layer of pedon 05. Photo: Markku Yli-Halla.

pedons 04...09. In addition to clay, many pedons have thin strata of silt. These soils are artificially drained and they have a structure at least down to the depth of drainage tiles (about 1 m). In the upper part of the B horizon, the structure is (sub)angular blocky but in lower horizons it becomes prismatic. The matrix color is commonly 10YR 4/2. None of the clayey soils had the gleyic matrix colors (2.5Y or yellower) even in the deepest horizons sampled, differing from the clayey soils of the Helsinki area (Mokma et al. 2000). Instead, the prism faces in the Bg and BC horizons are grey (2.5–5Y 5/1). These faces represent the cracks through which most of the water drains away. All of these soils had many redox concentrations in the subsoil and were considered to have an aquic moisture regime. The ped faces do not have continuous coating of iron hydroxide and thus do not have the gleyic color pattern (FAO 1998). Cambic horizon was identified in all clayey soils on the basis of redox concentrations and structure. These soils are also characterized by black Mn nodules.

Pedon 05 is heavy clay with a very well developed prismatic structure. Large prismatic aggregates or peds occur immediately below the plow layer and could be picked by hand (Fig. 2). These prisms had a length of about 18 cm and a diameter of 5–7 cm, and at the end of a dry summer of 1999 there were cracks 1 cm wide between the prisms. Small slickensides, or pressure faces, were commonly observed at 35–40 cm, but they occurred also at 60 cm and 100–110 cm. Wedge-shaped peds with 60° angles were observed at 100–110 cm. This is the first pedon in Finland where vertic characteristics have been morphologically described. According to Soil Taxonomy, this pedon is tentatively classified as a Vertic Cryaquept, because the coefficient of linear extensibility was not determined.

In pedons 04, 06…08 pressure faces or wedge-shaped aggregates were not observed even though they do crack. The reason may be that the other pedons are closer to the bedrock high areas from which water is running as lateral flow. Pedon 05, being also close to a major ditch, may be drier and can be more conducive to cracking. Pedons 04, 06, 07 and 08 classify as Typic Cryaquepts according to Soil Taxonomy and Vertic Cambisols according to FAO-Unesco and WRB system. The Vertic Cambisol classification is in agreement with the Soil Map of Denmark, Finland, Norway and Sweden (Rasmussen et al. 1989) and the Soil Geographic Database of Europe (European Soil Bureau 1998).

Pedon 09 represents an area within the clayey fields which has a 45-cm topsoil of sandy loam while the subsoil is clayey. The sandy loam plow layer is sufficiently dark to meet the color

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requirements of a mollic epipedon. Also, other criteria of Mollisols (Soil Survey Staff 1998) and Phaeozems (FAO 1998) are met here but in the FAO-Unesco system (FAO 1988) and the earlier versions of Soil Taxonomy P content excluded this soil from those taxa. This soil is similar to the pedons Helsinki 02 and 03 (Mokma et al. 2000). Also in the Jokioinen area the mollic epipedons are met only in plow layers which are predominantly sandy while the clayey plow layers seem to have, owing to a lighter dry color, ochric epipedons.

Soils containing organic materials

Pedon 10 is in the lowest position of this landscape (80 m), behind the levee of the river Loimijoki. This area floods frequently and pedon 10 has 39 cm of mineral soil material over sapric materials. These sapric materials became darker in color within a few minutes after exposure to air, suggesting that these horizons are continuously saturated. This pedon has a uniform texture throughout the investigated depth, suggesting that the source of the sediment has not changed over time. The sapric materials indicate more abundant water / biological activity during the deposition of those horizons and stability of land surfaces as compared to the earlier or more recent times when mineral materials were deposited. The histic horizon between 39 and 110 cm is diagnostic for Histosols of Soil Taxonomy and FAO-Unesco system and the pedon classifies as a Terric Cryosaprist (Soil Survey Staff 1998) and a Terric Histosol (FAO 1988).

According to the WRB system, pedon 10 is not a Histosol because the histic horizon doesn't start within 30 cm of soil surface. Strictly following the Key (FAO 1998), this soil is a Cambisol, a name which poorly reflects the properties of this soil, neglecting the organic materials which present stability problems for use and management. This soil is saturated with water for considerable periods and has continuous coatings of Fe hydroxide on ped faces at 39–80 cm. Even though the matrix color of those horizons is 10YR, not 2.5Y or yellower, we conclude that this soil has gleyic properties below 39 cm. A name Thaptohistic Gleysol (FAO 1998) is in accordance with soil properties and topographic position of this soil.

Sapric materials also occur in local depressions higher in the landscape which have no or limited outlets for water like pedon 11 at an elevation of 108 m. In this pedon 1-m thick sapric materials have accumulated on heavy clay (82% clay) which has deposited between ridges of glacial till. This pedon classifies as a Terric Cryosaprist (Soil Survey Staff 1998), Terric Histosol (FAO 1988), and Sapric Histosol (FAO 1998).

Conclusions

The catena of this landscape (Table 4) represents a toposequence from high to low elevations and a hydrosequence from dry to wet sites, except the organic soils which can occur at any elevation in local depressions. Owing to the absence of the gleyic color pattern in clayey soils, it can be concluded that these cultivated soils would have cambic horizons even if there were no human influence, as opposed to the clayey soils in Helsinki (Mokma et al. 2000) which are younger and have a lower topographic position. Even though the predominant clay mineral in these soils is illite (Sippola 1974), very high clay content is conducive to cracking but the climate may be too cool and humid for the soil to crack sufficiently for the development of Vertisols.

Weakly developed Spodosols/Podzols are present in forested sandy soils with minimum clay and silt contents but it is likely that much of the forested sandy loam soils of the area are not Spodosols/Podzols. Owing to the differences in the criteria of the cambic horizon in the FAO-Unesco and WRB systems, many of the sandy loam soils are Regosols in the FAO-Unesco system and Cambisols in the WRB system. Some cultivated soils which have a sandy loam plow layer are Cambisols in the FAO-

Table 4. Relationships between the landforms and soils in the Jokioinen landscape according to Soil Taxonomy (Soil Survey Staff 1998), FAO-Unesco system (FAO 1988) and Word Reference Base for Soil Resources (WRB) system (FAO 1998).

Classification system	Landform					
	Dry esker	*Depression*	*Bedrock high*	*Cultivated land, sandy*	*Cultivated land, clayey*	*Floodplain*
Soil Taxonomy	Entic Haplocryods	Terric Cryosaprists	Typic Dystrocryepts	Aquic Haplocryolls, Aquic Eutrocryepts	Typic and Vertic Cryaquepts	Terric Cryosaprists
FAO- Unesco	Haplic Podzols	Terric Histosols	Dystric Regosols	Eutric Cambisols, Dystric Regosols	Vertic Cambisols	Terric Histosols
WRB	Haplic Podzols	Sapric Histosols	Dystric Cambisols	Haplic Phaeozems, Dystric Cambisols	Vertic Cambisols	Thaptohistic Gleysols

Unesco system and Phaeozems in the WRB system. The Cambisols of these two systems seem to have different morphologies. In this landscape, Soil Taxonomy and the WRB system classify mineral soils quite analogously, particularly Inceptisols and Mollisols (Soil Survey Staff 1998) being equivalent to Cambisols and Phaeozems (FAO 1998), respectively.

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SELOSTUS

Jokioisten seudun maannokset

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Jokioisissa tutkittiin 11 maaprofiilia noin 1,5 metrin syvyyteen ja määritettiin niissä esiintyvät maannokset. Maista kahdeksan oli viljeltyjä, kaksi oli metsämaita ja yksi Loimijoen tulva-alueella oleva entinen viljelymaa. Maannokset nimettiin amerikkalaisen Soil Taxonomy -järjestelmän, FAOn-Unescon järjestelmän (FAO) ja World Reference Base for Soil Resources -järjestelmän (WRB) mukaan. Tutkitut maat ovat 80–130 m meren pinnan yläpuolella ja ne ovat olleet alttiina maannostumisprosesseille yli 8000 vuotta. Kuivan ja hiekkaisen Kukonharjun maa oli podsoloitunutta, mutta hienojakoisemmassa metsämaassa ei vielä voitu havaita podsolille tyypillistä valkomaakerrosta, vaikka maa oli hapan ja siinä oli matala emäskyllästysaste. Kaikkiin viljeltyihin kivennäismaihin oli kehittynyt rakenne salaojitussyvyyteen saakka, ja niissä oli ruostelaikkuja. Tällä perusteella niissä katsottiin olevan cambic-horisontti, ja maat olivat Cambisol-maita (FAO, WRB) ja Inceptisol-maita (Soil Taxonomy). Yhdessä aitosavimaassa oli runsaan halkeilun lisäksi maakokkareiden kutistumisesta ja turpoamisesta johtuvia liukupintoja, jollaisia ei ole Suomessa ennen todettu. Maassa, jonka muokkauskerros oli karkeaa hietaa ja syvemmät kerrokset savea, oli viljelytoimien seurauksena syntynyt mollic-pintakerros, ja tämä maa oli Mollisol (Soil Taxonomy) tai Phaeozem (WRB). Tutkittu viljelty turvemaa on syntynyt aitosavipohjalle. Loimijoen luhta-alueella on kivennäismaakerrosten alla 30–40 % orgaanista ainesta sitältäviä maakerroksia. Soil Taxonomy -järjestelmän pääryhmistä alueelta löytyi Spodosol-, Inceptisol-, Mollisol- ja Histosol-luokkiin kuuluvia maita, FAOn-Unescon järjestelmän Podzol-, Regosol-, Cambisol- ja Histosol-luokkiin kuuluvia maita ja WRB-järjestelmän Podzol-, Cambisol-, Phaeozem-, Gleysol- ja Histosol-maita.