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Soil Genesis

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TOPOSEQUENCE AND PROPERTIES OF SOILS IN THE HILLY LANDSCAPE OF LIER (BUSKERUD REGION, SOUTH NORWAY)

Abstract. The research was carried out in the hilly landscape in the Buskerud region, south Norway. The following soil toposequence was stated, beginning from the top of the slope: Epigleyic Pheozem (Siltic) – Cumullinovic Pheozem (Endosiltic) – Epigleyic Pheozem (Skeletic Endosiltic) – Cumullinovic Pheozem (Siltic) – Mollic Gleysol (Siltic). The soils had a silt loam and sandy loam texture with a substantial admixture of gravel. The material was poorly sorted with a lepto – and platykurtic texture distribution. The amounts of organic matter, organic carbon, as well as total nitrogen and phosphorus did not show catenal changes.

The areas with a diversified relief are particularly vulnerable to the translocation of soil material on the slope. This process is induced and accelerated by human agricultural activity [16]. The functioning of these areas may be assessed by using linear patterns of the soil cover, i.e. soil toposequences, which include soil catenas and soil chronosequences [6]. Initial unused slopes are typical eroded catenae in a young glacial landscape [5]. However, when they are agriculturally used, they are altered into downward-translocation catenae [20].

The translocation of the soil material on the slope, as a result of agricultural soil use, plays a key role in modifying the soil cover of the slope agricultural landscapes [5, 22]. This leads to the alternation of the original soil cover and formation of specific soil toposequences [21]. An important element in these patterns are deluvial soils. [1, 23]. The formation of these soils is a result of erosional processes occurring in the upper parts of the slope and accumulative processes occurring in concave parts and at the bottom of the slopes [5, 17].

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Deluvial soils have specific properties [1, 11, 19] and are an indicator of environmental modifications induced by agricultural human activity [12].

STUDY AREA

The research was carried out in 2009 in a hilly landscape in Lier, in the Buskerud region, south Norway (59° 47' 31.40" N, 10° 14' 53.04"). The study area was located in the Lier river valley, which flows into the Drammen Fiord (Fig. 1). The study area was described on the base of archive materials from the Norwegian Forest and Landscape Institute [10]. The postglacial valley, currently used by the Lier river, is filled with marine deposits that built the hills. Flat areas, located closer to the river, are related to the accumulation of alluvial deposits. The deposits have a silt, loam and loamy sand texture. The erosional risk determined according to the USLE model, ranged from high at the top of the hills to low on the flat areas. The soil cover of the studied area included main groups of soils from the WRB system, such as Albeluvisols, Stagnosols and Cambisols. These soils had medium, (3–6%), rarely low (0–3%) organic matter content, as well as very high and high water capacity. The studied soils were agriculturally used under spring barley (*Hordeum vulgare*) cultivation.

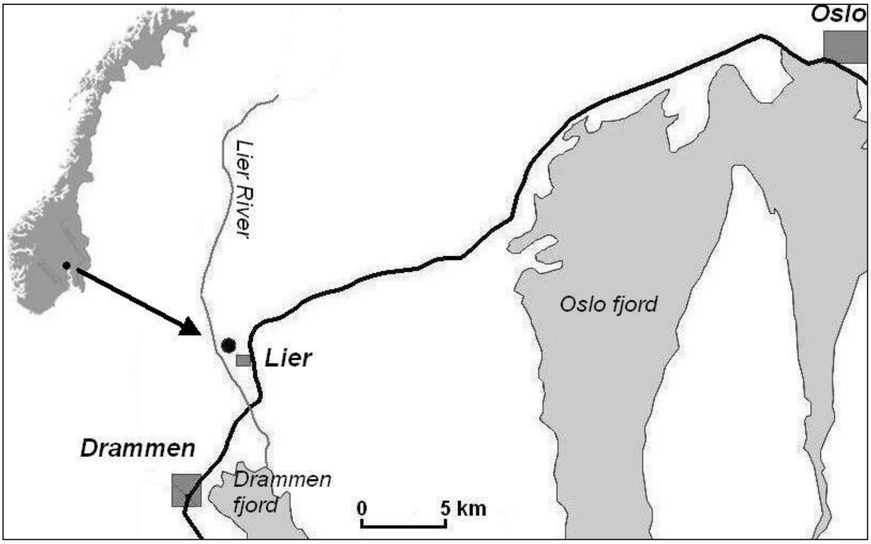

Fig. 1. Location of the research area.

METHODS

In the studied area, a soil catena was made from the top of the slope towards a depression. Six soil profiles were described and twenty soil samples were taken. In the laboratory, the following soil properties were analyzed [3]: soil texture according to the hydrometer method of Bouyoucos modified by Cassagrande and Prószyński with the separation of sand sub-fractions by dry sieving, pH in deionized water and potassium chloride (1 mol dm^{-3}) potentiometrically, $CaCO_3$ according to the Scheibler method, organic matter content after dry ashing at the temperature of 550 °C, organic carbon content according to the Tiurin method, total nitrogen content according to the Kjeldahl method, phosphorus content – colorimetrically.

The soil texture classes were determined according to the classification of the Polish Society of Soil Science [13], consistent with the USDA classification system. The results of the particle size analysis (percentage of fractions) were analyzed using the SIEWCA computer program [4] in order to draw granulometric curves and calculate sedimentological indices of Folk and Ward [14]. For the granulometric analyses, the following indices were used: mean diameter (Md), standard deviation (δ_1), skewness (Sk_1) and kurtosis (K_G).

The soils were classified according to the WRB system [7], and the horizon symbols according to the Polish Soil Classification System [9].

RESULTS AND DISCUSSION

The toposequence of the studied soils is shown in Figure 2. The results of the texture analysis and sedimentological indices are presented in Tables 1 and 2.

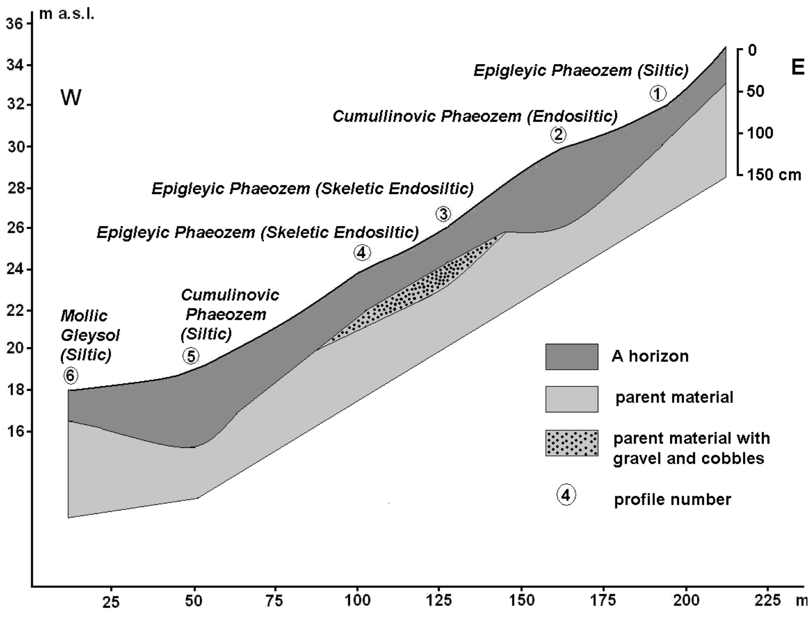

Fig. 2. Soil toposequence of the catena Lier.

TABLE 1. TEXTURE AND SEDIMENTOLOGICAL INDICES OF CATENA LIER SOILS

Horizon	Depth (cm)	Particle size (mm)				Mz	δ_1	Sk_1	K_g
		>2.0	2.0–0.05	0.05–0.002	<0.002				
		%					phi		
Profile 1 – Epigleyic Pheozem (Siltic)									
Ap	0–40	2	32	67	1	0.033	2.251	-0.108	1.088
C1g	40–50	6	30	69	1	0.032	2.169	-0.902	1.148
C2	50–150	2	29	68	3	0.035	2.113	-0.140	1.356
Profile 2 – Cumullinovic Pheozem (Endosiltic)									
Ap	0–32	5	48	49	3	0.056	2.767	-0.092	0.801
A2	32–56	8	47	49	4	0.053	2.853	-0.105	0.798
Ab	56–92	3	30	60	10	0.029	2.803	0.035	1.663
C1gb	92–118	23	39	65	1	0.032	2.640	0.062	1.203
C2b	118–150	0	34	65	1	0.035	2.137	0.191	0.826
Profile 3 – Epigleyic Pheozem (Skeletic Endosiltic)									
Ap	0–38	12	32	58	10	0.033	2.927	0.052	1.785
Cg	38–62	82	59	39	2	0.075	2.774	0.230	0.705
2C	62–150	0	17	73	10	0.015	2.083	0.246	1.008
Profile 4 – Epigleyic Pheozem (Skeletic Endosiltic)									
Ap	0–45	19	35	62	3	0.054	2.287	-0.206	1.519
Cg	45–64	41	57	41	2	0.082	2.744	0.183	0.678
2C	64–150	0	20	71	9	0.015	2.094	-0.214	1.212
Profile 5 – Cumullinovic Pheozem (Siltic)									
Ap	0–33	9	36	60	4	0.040	2.582	-0.152	0.880
A2	33–46	8	31	65	4	0.032	2.503	-0.168	1.154
A3	46–86	3	26	70	4	0.024	2.140	-0.120	1.299
Cgg	86–150	15	31	65	4	0.027	2.125	-0.036	1.149
Profile 6 – Mollic Gleysol (Siltic)									
Ap	0–32	1	18	79	4	0.020	1.609	-0.072	1.295
Gc	32–150	20	27	69	4	0.026	2.118	-0.110	1.168

TABLE 2. SELECTED PROPERTIES OF CATENA LIER SOILS

Horizon	Depth (cm)	Textural class	Organic matter (%)	pH		$CaCO_3$ (%)	$C_{org.}$	$N_{tot.}$	$P_{tot.}$	C:N	N:P
				H_2O	KCl		g·kg^{-1}				
Profile 1 – Epigleyic Pheozem (Siltic)											
Ap	0–40	SiL	4.65	7.03	6.52	-	14.12	1.40	0.15	10.1	9.3
C1g	40–50	SiL		7.16	6.56	-					
C2	50–150	SiL		7.05	6.12	-					
Profile 2 – Cumullinovic Pheozem (Endosiltic)											
Ap	0–32	SL	3.32	7.13	6.24	-	9.36	0.85	0.08	11.0	10.6
A2	32–56	SL	2.67	7.03	6.12	-	6.60	0.76	0.08	8.7	9.5
Ab	56–92	SiL	4.54	6.95	6.16	-	11.93	1.51	0.10	7.9	15.1
C1gb	92–118	SiL		6.86	5.71	-					
C2b	118–150	SiL		6.93	5.96	-					
Profile 3 – Epigleyic Pheozem (Skeletic Endosiltic)											
Ap	0–38	SiL	4.68	7.02	6.27	-	14.98	1.54	0.13	9.7	11.9
Cg	38–62	SL		7.28	6.26	-					
2C	62–150	SiL		6.69	5.47	-					
Profile 4 – Epigleyic Pheozem (Skeletic Endosiltic)											
Ap	0–45	SiL	4.65	7.01	6.31	-	12.17	1.28	0.13	9.5	9.9
Cg	45–64	SL		7.12	6.10	-					
2C	64–150	SiL		6.67	5.42	-					
Profile 5 – Cumullinovic Pheozem (Siltic)											
Ap	0–33	SiL	4.32	7.03	6.55	-	15.60	1.49	0.21	10.5	7.1
A2	33–46	SiL	3.22	7.08	6.57	-	14.04	1.43	0.22	9.8	6.5
A3	46–86	SiL	4.85	6.87	6.24	-	16.61	1.70	0.20	9.8	8.5
Cgg	86–150	SiL		6.75	6.19	-					
Profile 6 – Mollic Gleysol (Siltic)											
Ap	0–32	Si	4.64	7.70	7.57	0.4	15.99	1.53	0.29	10.5	5.3
Gc	32–150	SiL		7.89	7.57	-					

SiL – silt loam, Si – silt, SL – sandy loam.

At the top of the slope Epigleyic Phaeozem (Siltic) of a silt loam texture was located. The soil contained 1–3% of clay fraction, had a low mean particle diameter (0.032–0.035 mm) and was poorly sorted. The skewness was negative with the predominance of coarse fractions and elimination of finer fractions. Such distribution is typical for eroded soils. The described soil had a mezo – and leptokurtic texture distribution (Table 1). Subsequently, the deluvial soil on the fossil soil occurred, and was classified as Cumullinovic Phaeozem (Endosiltic) (Fig. 2). The occurrence of deluvial soils in the upper parts of the slope may be related to the original shape of the slope and accumulation of deluvial deposits in the concave parts [5, 17]. Deluvial horizons of the studied soil (which had a thickness of 56 cm) had a sandy loam texture with a higher mean diameter of particles (0.053–0.056 mm), with predominant coarser fractions and a platykurtic texture distribution. Deeper horizons of the original soil had a silt loam texture and a mean particle diameter similar to profile 1, as well as a leptokurtic or very leptokurtic (K_g 1.785) texture distribution. The value of the skewness indicator suggests the dominance of finer fractions (Table 1). At the middle of the slope, Epigleyic Phaeozem (Skeletic Endosiltic) occurred. This soil had the most diversified texture among all studied soils. The soil had a silt loam (gravelly silt loam) texture interbedded by sandy loam (very or extremely gravelly sandy loam) (Fig. 2, Table 1). The mean particle diameter amounted to 0.015–0.082 mm and the standard deviation reached the values of >2 (very poorly sorted material). Moreover, these soils had various indices of skewness and kurtosis, which suggests an unstable environment of sedimentation [14]. Another element in the toposequence was the deluvial soil classified as Cumullinovic Phaeozem (Siltic), located in the lower part of the slope. It had an almost homogenous texture of a silt loam in the soil profile, low mean particle diameter (0.024–0.040 mm) and was poorly sorted. The texture distribution was platykurtic in the Ap horizon and leptokurtic in deeper horizons. The studied toposequence was terminated by the gley soil classified as Mollic Gleysol (Siltic) with a silt loam texture and a clay content of 4%. The studied soil had a low medium particle diameter (0.020–0.026 mm), was better sorted in the surface horizon and had a leptokurtic texture distribution in the whole soil profile.

In summary, the clay fraction in the studied soils was translocated down the slope. Lack of significant translocation of finer fractions may be a result of too short of a transport of the soil material [18], and a non-intense agricultural treatment during autumn, which diminishes the erosional processes [2]. Sedimentological indices (mainly Md, δ_1, K_g) in the studied soil toposequence were typical for glacial loams.

The soil reaction of the studied toposequence ranged from slightly acidic to neutral (Table 2). In surface horizons, the values of pH_{KCl} were similar, ranging from 6.12 to 7.57 and decreasing down the soil profile (Table 2). Although the pH values were high, $CaCO_3$ was stated only in the Ap horizon in profile 6

(Table 2). Such conditions may be a result of the alkaline character of the marine deposits, which built the analyzed hill.

The studied soils had high organic matter content (Table 2). In humus horizons of the Epigleyic Phaeozem, it amounted to 4.64–4.68%. Lower amounts of organic matter were stated in the deluvial horizons of the Cumullinovic Phaeozem – 2.97–4.85%. The highest contents of organic carbon (14.04–16.61 $g \cdot kg^{-1}$) were stated in the soils located in the lower parts of the slope – Cumullinovic Phaeozem and Mollic Gleysol. The Cumullinovic Phaeozem (profile 2) contained the lowest amounts of OC in the deluvial horizons (6.60–9.36 $g \cdot kg^{-1}$). Similar relations were observed for total nitrogen and total phosphorus (Table 2).

Deluvial soils had the C/N ratio ranging from 8.7 to 11.0. In other soils, the ratio amounted to 9.5–10.5. These values suggest high biological activity and high soil fertility. Similar values of C/N ratios in deluvial and eroded soils are related to similar properties of these soils (soil texture, soil reaction) [1]. The N/P ratio ranged from 5.3 to 11.9. Sapek [15] stated that in the soils occurring in natural ecosystems the N/P ratio amounted to 20:1, whereas in agriculturally used soils it amounted to 3:1. Higher values of the N/P ratio in the studied soils suggest that these soils are not intensively used.

CONCLUSIONS

1. Soils occurring in a hilly young glacial landscape in southern Norway had the following toposequence: Epigleyic Pheozem (Siltic) – Cumullinovic Pheozem (Endosiltic) – Epigleyic Pheozem (Skeletic Endosiltic) – Cumullinovic Pheozem (Siltic) – Mollic Gleysol (Siltic).
2. The studied soils had the silt loam and sandy loam texture with the high admixture of the gravel fraction. The translocation of the silt and clay fraction down the slope was not significant.
3. The soils were poorly sorted and had various sedimentological environments, which was mainly related to the enrichment in coarser fractions and elimination of finer ones, as well as the lepto – and platykurtic texture distribution.
4. The amounts of organic matter, organic carbon, total nitrogen and total phosphorus did not change catenally.
5. The C/N ratio suggests high biological activity and soil fertility, and the N/P ratio indicates moderate agricultural use of soils.

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TOPOSEKWENCJA I WŁAŚCIWOŚCI GLEB W PAGÓRKOWATYM KRAJOBRAZIE LIER (REGION BUSKERUD – POŁUDNIOWA NORWEGIA)

Badania prowadzono w pagórkowatym krajobrazie w regionie Buskerud w południowej Norwegii. Stwierdzono występowanie następującej toposekwencji gleb poczynając od górnej części stoku: Epigleyic Pheozem (Siltic) – Cumullinovic Pheozem (Endosiltic) – Epigleyic Pheozem (Skeletic Endosiltic) – Cumullinovic Pheozem (Siltic) – Mollic Gleysol (Siltic). Gleby charakteryzowały się uziarnieniem pyłów iglastych i glin piaszczystych o dużym udziale części szkieletowych. Głównymi cechami materiału glebowego było bardzo słabe wysortowanie oraz lepto – i platykurtyczny rozkład uziarnienia. Nie stwierdzono katenalnych zmienności zawartość materii organicznej, węgla organicznego oraz całkowitych form azotu i fosforu.