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Soil Genesis

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INFLUENCE OF LITHO-MORPHOGENETIC, HYDROLOGIC AND ANTHROPOGENIC FACTORS ON SORPTIVE AND BUFFER PROPERTIES OF SOILS OF EROSIONAL-DENUDATIONAL VALLEYS: CASE STUDY FROM SŁAWIEŃSKA PLAIN

Abstract. The aim of the study has been to assess the role of litho-morphogenetic, hydrologic and anthropogenic factors influencing spatial variability of sorptive and buffer properties of the soils of erosional-denudational valley incised in hollow sediments flat-dipping glacial till in the area of Sławieńska Plain. Parent material properties, water - as a causative agent of erosion and ions carrier, as well as the quantity and the properties of organic matter were basic factors influencing spatial variability of sorptive and buffer properties of the examined soils. The sorption capacity of Stagnic Dystric Cambisols of the high plain formed of strongly acid, silt-clay hollow sediments ranged from 8.74 to 22.12 cmol(+) kg^{-1}. Acidic cations dominated in the sorption complex of the soils, but its percentage decreased with depth. Colluvic Regosols of the slopes had a lower content of clay and organic matter in relation to the soils of the high plain which was reflected in a lower sorption capacity. The cation exchange capacity of Colluvic Gleysols and Mollic Gleysols of the bottom of the valley ranged from 7.21 to 25.68 cmol(+) kg^{-1} and was positively related to the content of soil organic matter and clay. The high base saturation of the soils (97.2–100.0%) was an effect of the influence of supplying water. Calcium dominated among base cations. The soils of the high plain and slopes had high buffering capacity of basis and low of acids. Higher buffering capacity of acids found in the soils of the valley bottom was an effect of almost full saturation of soil sorption complex with exchangeable basis.

Erosional-denudational valleys, as small relief forms of periglacial genesis have been the subject matter of geomorphological studies for many years. The studies provide information about the history of landscape evolution in different areas [3, 13, 14, 15, 18, 29, 32]. Vertical variability of physical and chemical properties of sediments in the bottom of the valleys is the reflection of

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environmental conditions changing over time and human activity in the catchment [30, 34]. The properties of the sediments in the valley bottoms are being shaped by the properties of materials building the high plain and the direction as well as the range of its transformation during the transport along the slopes and after deposition. During the pauses in the deposition of colluviums, in the bottom of the valleys develop soils in the direction appropriate to the properties of the parent material, the hydrological conditions and the configuration of other soil-forming factors. The presence of the buried soils in the bottom of erosional-denudational valleys indicates the periods of time with the presence of permanent plant cover, which decreases the erosion of slopes, and limited anthropopressure on the environment. Erosional-denudational valleys are environments of high spatial diversity of soil types and variability of its properties [10], but are weakly recognized in this regard.

The aim the studies has been to assess the role of litho-morphogenetic, hydrologic and anthropogenic factors influencing spatial variability of sorptive and buffer properties of the soils of erosional-denudational valleys incised in hollow sediments flat-dipping glacial till in the area of Sławieńska Plain.

MATERIALS AND METHODS

The studies were conducted in the erosional-denudational valley located a few hundred meters west of Mazów in the area of Sławieńska Plain (Fig. 1). The length of the valley is about 200 m and its maximum depth about 10 m. The valley is incised in Pleistocene hollow sediments of the thickness of about 5 m flat-dipping on strongly compacted glacial till with the content of carbonates of about 5%. The interbeddings of sands occurring between the hollow sediments and glacial till are water-bearing layer. The bottom of the valley is currently filled with slope sediments of thickness exceeding 4 m (Fig. 4) and dating in its bottom to 590±55 years BP [31]. The filling of the valley bottom with slope sediments was the effect of deforestation of the catchment in Middle Ages and the initialization of intensive water erosion. The morphogenesis of the studied erosional-denudational valley is described by Tylman [30]. At present, the valley is covered with age-differentiated European beech and its catchment is used for agricultural purposes. At the turn of the 19th and the 20th century and in the year 1966 the catchment was drained. Drainage water outflow in two points in the upper part of the valley (Fig. 2) and the outflow is periodic.

Field studies were conducted during the spring of 2007. 19 soil profiles located in high plain, slopes and the bottom of the valley were done, described, and sampled. The taxonomic status of the examined soils was determined in accordance with the World Reference Base –WRB [7]. Six profiles representing all noticed soil types were selected for the purposes of the study (Fig. 3).

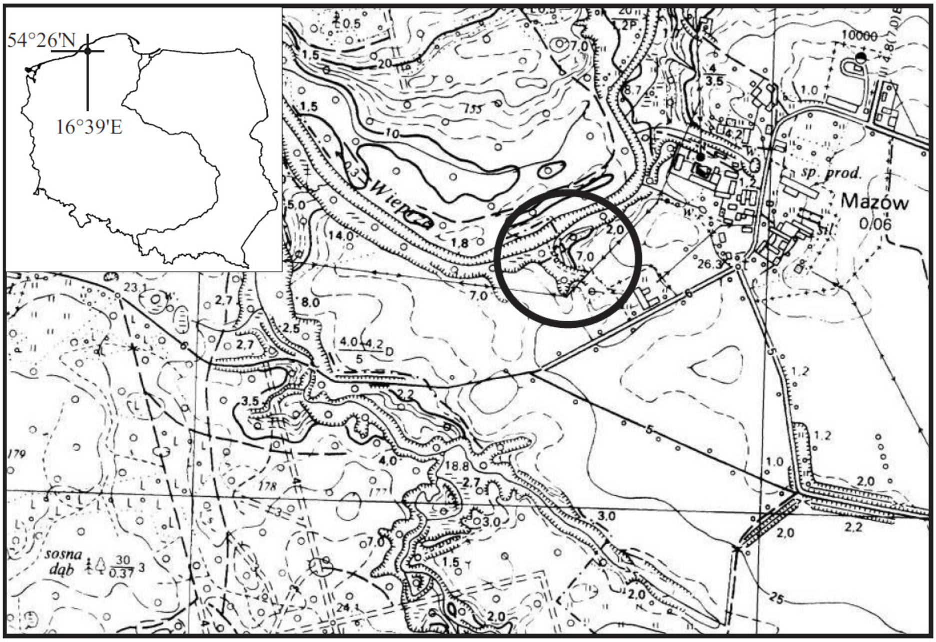

Fig. 1. Location of erosional-denudational valley.

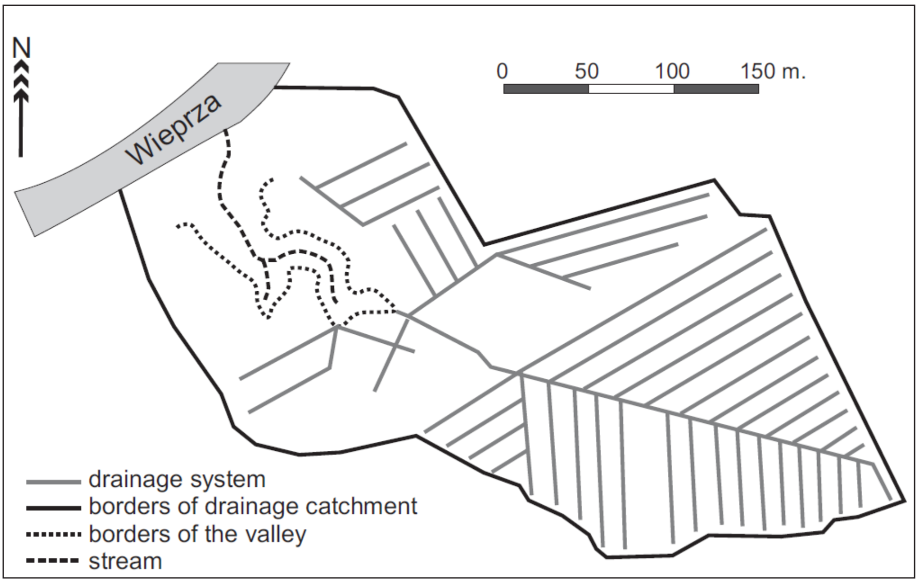

Fig. 2. Drainage system in the catchment of erosional-denudational valley.

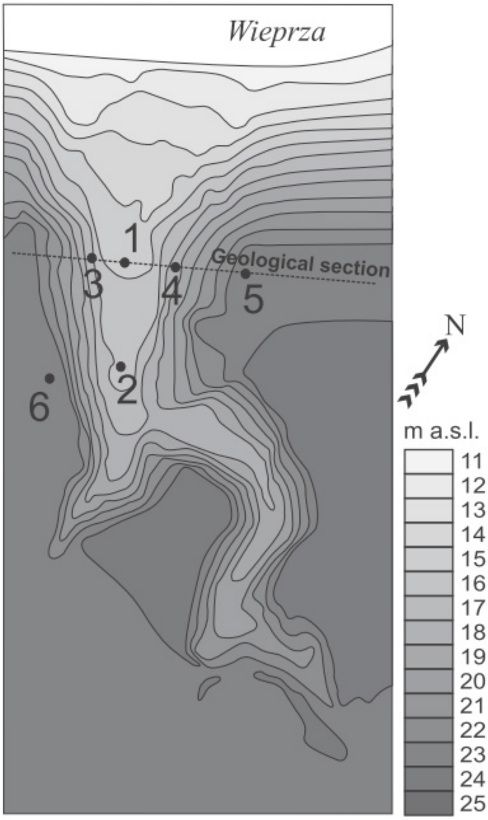

Fig. 3. Location of soil profiles in erosional-denudational valley.

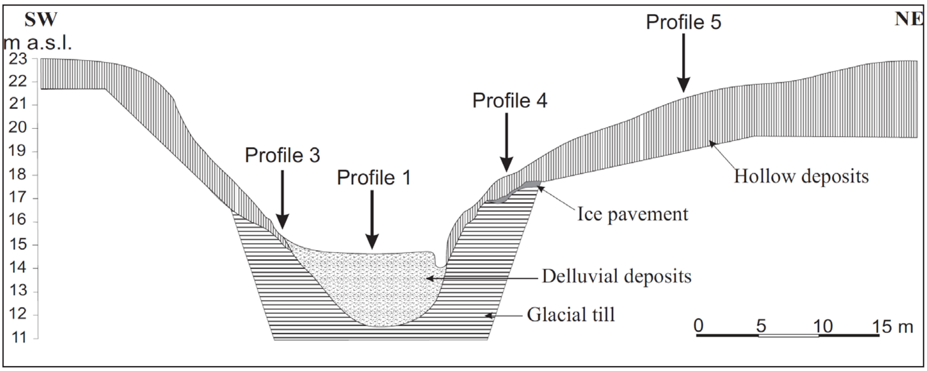

Fig. 4. Geological section of the erosional-denudational valley.

Soil samples were taken from every horizon as monoliths and as samples with undisturbed structure using 100 cm^3 steel rings. The following properties were analyzed with standard methods used in soil science [2]:

– particle size distribution by mixed sieve and pipette methods (textural fractions and groups were divided according to the classification of the Polish Soil Science Society, 2008),
– bulk density by gravimetric method,
– specific density by burette method,
– specific surface area by the method of glycerine vapours adsorption,
– content of carbonates by Scheibler method,
– pH in H_2O and 1M KCl solution potentiometrically,
– loss on ignition in 550°C,
– the content of total organic carbon (TOC) by Tiurin method,
– the content of total nitrogen (TN) by Kjeldahl method,
– the content of exchangeable basis in 1M solution of CH_3COONH_4,
– exchangeable acidity and exchangeable aluminum by Sokolov method,
– hydrolytic acidity by Kappen method,
– buffer properties by Arrhenius method.

The following were calculated based on the results:
– total porosity based on bulk density and specific density,
– the sum of exchangeable basis (TEB),
– cation exchange capacity (CEC) as sum of exchangeable basis and exchangeable acidity,
– base saturation (BS),
– buffering areas of acids (P_{HCl}) and alkali (P_{NaOH}) using computer programs EXCEL and ARC GIS.

Spearman's correlation coefficients between selected properties of the soils were calculated using computer program STATISTICA.

RESULTS

Physical and Chemical Properties

Stagnic Dystric Cambisols were found in the high plain part of the catchment represented by profile 6 (Fig. 3). The soils were formed of hollow sediments of the texture of silt clay with the content of clay up to 50%, comparable content of silt and low admixture of sand (Table 1). Lower content of clay found in A, Bw and Cg1 horizons of the soils is probably the effect of the eluviation of the fraction on the edge of the high plain. Bulk density of the soils varied from 1.01 g cm^{-3} in humic horizon up to 1.62 g cm^{-3} in parent material. Total porosity ranged from 39.4 to 60.0% (Table 2). Specific surface area of the soils varied from 34.0 m^2 g^{-1} in Cg1 horizon to 88.3 m^2 g^{-1} in Cg3 horizon. The pH was strongly acid and varied from 4.2 in A horizon to 5.0 in C3g horizon. Humic horizon contained 3.52% of TOC and 0.160% of TN (Table 2).

TABLE 1. PARTICLE SIZE DISTRIBUTION IN THE SOILS OF EROSIONAL-DENUDATIONAL VALLEY

Horizon	Depth (cm)	% of particles with diameter (mm)				Textural group
		> 2.0	2.0–0.05	0.05–0.002	< 0.002	
Profile 1 – Colluvic Gleysol – bottom						
A	0–17	0.0	35.1	50.8	14.1	silt loam
AG	17–28	0.6	39.1	46.3	14.6	loam
G1	28–41	0.0	28.2	55.2	16.6	silt loam
G2	41–62	0.0	32.3	49.7	18.0	loam
G3	62–110	0.0	35.6	54.8	9.6	silt loam
Profile 2 – Colluvic Gleysol – bottom						
A	0–18	0.0	32.4	49.7	17.9	loam
G1	18–40	0.0	23.9	54.9	21.2	silt loam
G2	40–50	0.0	46.6	43.3	10.1	loam
G3	50–64	0.0	40.5	48.0	11.5	loam
G4	64–70	0.0	73.7	20.6	5.7	sandy loam
G5	70–150	0.0	47.7	42.4	9.9	loam
Profile 3 – Mollic Gleysol – bottom						
A	0–20	1.1	50.4	39.7	9.9	loam
Ag	20–67	0.0	54.4	42.5	3.1	sandy loam
G	67–100	1.9	74.4	16.4	9.2	sandy loam
Profile 4 – Dystric Cambisol - slope						
A	0–8	0.6	71.2	26.2	2.6	sandy loam
Bw	8–35	3.0	62.8	20.7	16.5	sandy loam
Cg1	35–60	3.8	47.0	34.3	18.7	loam
Cg2	60–75	36.8	57.0	26.8	16.2	sandy loam
2Ccag	75–100	24.1	62.5	24.8	12.7	sandy loam
Profile 5 – Colluvic Regosol - slope						
A	0–25	0.1	62.7	33.9	3.4	sandy loam
ABw	25–106	0.2	44.2	43.9	11.9	loam
C	106–150	0.9	46.6	33.7	19.7	loam
Profile 6 – Stagnic Dystric Cambisol – high plain						
A	0–15	0.2	39.6	51.2	9.2	silt loam
Bw	15–54	0.0	17.1	65.8	17.1	silt loam
Cg1	54–94	0.0	30.0	59.1	10.9	silt loam
Cg2	94–114	0.0	2.8	49.0	48.2	silty clay
Cg3	114–150	0.0	4.0	42.4	53.6	silty clay

TABLE 2. SELECTED PHYSICAL AND CHEMICAL PROPERTIES OF THE SOILS

Horizon	Bulk density (g cm^{-3})	Total porosity (%)	Specific surface area (m^2 g^{-1})	pH_{H_2O}	pH_{KCl}	$CaCO_3$ (%)	Loss on ignition (%)	TOC (%)	TN (%)	TOC /TN
Profile 1 – Colluvic Gleysol – bottom										
A	0.82	66.9	54.2	5.6	4.9	0.0	11.2	4.76	0.350	13.6
AG	0.77	68.4	65.3	6.1	5.4	0.0	11.2	4.56	0.350	13.0
G1	0.92	63.0	79.8	5.5	4.7	0.0	10.1	4.05	0.330	12.3
G2	1.33	48.3	43.1	5.9	4.9	0.0	5.5	2.09	0.270	7.7
G3	1.18	52.1	52.0	5.7	4.9	0.0	9.3	4.20	0.270	15.6
Profile 2 – Colluvic Gleysol – bottom										
A	0.84	66.0	76.5	5.9	5.5	0.0	12.5	5.24	0.370	14.2
G1	1.31	49.9	52.4	6.3	5.2	0.0	5.4	2.11	0.150	14.0
G2	1.24	52.2	36.0	5.8	5.0	0.0	4.9	1.98	0.140	14.1
G3	1.22	52.2	40.0	5.8	4.9	0.0	4.9	2.24	0.150	14.9
G4	1.30	50.0	27.3	6.2	5.4	0.0	3.3	1.48	0.090	16.4
G5	1.17	54.5	55.9	5.9	5.0	0.0	6.5	2.77	0.170	16.3
Profile 3 – Mollic Gleysol – bottom										
A	0.53	78.3	54.9	6.6	6.0	0.0	19.5	9.20	0.490	18.8
Ag	0.63	74.4	33.6	5.7	5.2	0.0	12.9	4.07	0.220	18.5
G	1.91	28.8	29.2	8.3	7.6	2.4				
Profile 4 – Dystric Cambisol - slope										
A	1.17	54.7	40.5	4.6	3.6	0.0	6.5	3.07	0.160	19.4
Bw	1.37	48.8	34.0	5.3	4.0	0.0	2.9	0.35	0.020	22.5
Cg1	1.54	42.2	43.6	6.9	5.2	0.0				
Cg2	-	-	63.5	7.7	6.6	0.1				
2Ccag	1.96	27.4	22.8	8.2	7.5	4.7				
Profile 5 – Colluvic Regosol - slope										
$A_{del.}$	0.99	62.3	22.5	4.3	3.5	0.0	4.2	1.65	0.090	18.3
ABw_{del}	1.36	45.9	28.9	4.5	3.5	0.0	3.5	1.11	0.060	18.5
C	1.71	36.8	39.1	5.1	3.6	0.0				
Profile 6 – Stagnic Dystric Cambisol – high plain										
A	1.01	60.0	40.5	4.2	5.5	0.0	8.8	3.52	0.160	22.0
Bw	1.32	51.0	40.7	4.3	5.2	0.0	3.7	0.63	0.040	15.8
Cg1	1.62	39.4	34.0	4.7	5.0	0.0				
Cg2	1.32	49.8	62.4	4.7	4.9	0.0				
Cg3	1.37	48.9	88.3	5.0	5.4	0.0				

Spatial distribution of soil types on the slopes referred to the original morphology of the slopes and a mosaic of eroded Dystric Cambisols (profile 4) and Colluvic Regosols (profile 5) was found. In the profile number 4, located in the lower part of the slope, contact zone between hollow sediments and glacial till was found. On the border of the sediments of different genesis pavement layer occurred (horizon Cg2), which was likely due to the erosion of slope surface in the initial stages of the development of the valley, and than was covered with hollow sediments eroded from the high plain. Hollow sediments (horizons A, Bw, Cg1) had the texture of sandy loams and loams, and glacial till – sandy loam. Hollow sediments and glacial till differed in terms of physical and chemical properties. Bulk density increased with depth from 1.17 g cm^{-3} in A horizon up to 1.54 g cm^{-3} in horizon Cg1. Very high bulk density (1.96 g cm^{-3}) and extremely low total porosity (27.4%) was found in 2Ccag horizon (Table 2). Specific surface area in the horizon was relatively low (22.8 m^2 g^{-1}) in relation to the other horizons (34.0–63.5 m^2 g^{-1}). The reaction of the soil increased with depth from pH 4.6 in A horizon up to pH 8.2 in horizon 2Ccag which contained about 5% of carbonates. Humic horizon was rich in TOC (3.07%) and TN (0.160%), taking into account the location of the soil on the slope, but had a small thickness.

Colluvic Regosols on the slopes were formed of humic horizons of different thickness flat-lying on hollow sediments. The textural features of colluvial material were different from the material of the high plain (Table 1) what is an effect of its transformation during transport along the slopes and after deposition. Sand fraction dominated in colluvial material and the content of clay was maximum 12%. Bulk density in horizons formed from colluvial material was 0.99–1.36 g cm^{-3}, total porosity 45.9–62.3% and specific surface area ranged from 22.5–28.9 m^2 g^{-1} (Table 2). The pH of Colluvic Regosols was comparable to the soils of the high plain (4.3–4.5), but had lower content of TOC (1.65–1.11%) and TN (0.090–0.060%).

Colluvic Gleysols (profiles 1 and 2) formed of stratified slope material were found in the bottom of the valley. The texture of the soils was sandy loam, loam, loamy clay and silt clay (Table 2). The content of clay in the soils was lower in relation to the soils of the high plain and ranged from 5.7 up to 21,7%. Low bulk density (0.77–1.33 g·cm^{-3}) and high porosity (48.3–68.4%) were characteristic futures of the soils. Specific surface area ranged from 36.0 to 79.8 m^2 g^{-1}. High saturation with water favored the accumulation of organic matter. The content of TOC and TN was vertically varied. TOC ranged from 1.48 to 5.25%, and TN from 0.140 to 0.370%. The maximum content of the components in the surface horizon of the soils indicates reduction of slope processes in modern times and the accumulation of soil organic matter.

Mollic Gleysols (profile 3) characterized with a high content of organic matter, low bulk density (0.53–0.63 g cm^{-3}) and very high total porosity (74.4–78.3%)

(Table 2) occurred in the proximity of groundwater seepages. The content of TOC in the soils was up to 9.20% and TN to 0.490%. The pH was neutral and referred to the pH of the supplying water.

Sorptive Properties

Spatial variability of physical and chemical properties of the soils reflected in its sorptive properties. CEC of the soils ranged from 6.13 to 35.66 cmol(+) kg^{-1}. High values of CEC were found in rich in clay horizons Cg2 and Cg3 of the soils of the high plain (22.12 and 22.03 cmol(+) kg^{-1}), in horizon 2Cgca of profile 4 (27.49 cmol(+) kg^{-1}) and in the soils of the valley bottom, especially in Mollic Gleysol (up to 35.66 cmol(+) kg^{-1}) (Table 3). Minimum values were found in A and Bw horizons of profile 4 (6.13 i 6.14 cmol(+) kg^{-1}), in Colluvic Regosol in profile 5 (6.80–8.88 cmol(+) kg^{-1}), horizons A, Bw and Cg1 of the soils of the high plain (8.74–11.82 cmol(+) kg^{-1}) as well as in some horizons of Colluvic Gleysols in the bottom of the valley.

The soils varied in respect of the saturation of sorptive complex with particular cations. H^+ and Al^{3+} dominated in A and Bw horizons of the soils of the high plain. Base saturation increased with depth – from 2.2% in Bw horizon to 77.3% in horizon Cg3 (Table 3). Ca^{2+} was the main base, but in Cg2 and Cg3 horizons Mg^{2+} also had significant participation. The dominance of acidic cations was found in humic horizons of the soils of the slopes. The percentage of the basis in the horizons was only 13.4% in profile 5 and 35.0% in profile 4 (Table 3). The increase of base saturation was found with depth. In the soils of the valley bottom, both in Colluvic Gleysols and Mollic Gleysols, almost full saturation with bases was found (BS ranged from 97.3% to 100.0%) (Table 3) and calcium dominated in bases.

Buffer Properties

The examined soils were varied in respect of their buffer properties. Very acid, silty-clay soils of the high plain were characterized by high possibilities of the buffering of alkali (buffering areas from 42.85 to 60.57 cm^2) and low possibilities in relation to acids (buffering areas 5.30–11.52 cm^2) (Table 4). Similar regularities were found in profile 5 – Colluvial Regosols. In profile 4 horizons A and Bw (build of hollow sediments) had large possibilities of the buffering of alkali (buffering areas 49.96 and 29.03 cm^2) and low of acids (buffering areas 6.32 and 8.01 cm^2). A gradual inversion of the regularity was found with depth. In the horizon 2Cgca (glacial till) low buffering areas of alkali (3.05 cm^2) and large buffering areas of acids (40.55 cm^2) were observefound.

TABLE 3. SORPTIVE PROPERTIES OF THE SOILS

Horizon	Exchangeable cations						TEB	H_h	CEC	BS (%)
	Na^+	K^+	Ca^{2+}	Mg^{2+}	H^+	Al^{3+}				
	(cmol(+)·kg^{-1})									
Profile 1 – Colluvic Gleysol – bottom										
A	0.20	0.42	13.33	0.74	0.14	0.02	14.69	7.76	14.85	98.9
AG	0.26	0.45	16.57	1.21	0.06	0.00	18.49	6.82	18.55	99.6
G1	0.16	0.38	11.73	0.89	0.26	0.04	13.16	5.33	13.46	97.8
G2	0.11	0.25	7.46	0.17	0.10	0.03	7.99	7.87	8.12	98.5
G3	0.18	0.25	10.77	0.59	0.12	0.01	11.79	4.50	11.92	98.9
Profile 2 – Colluvic Gleysol – bottom										
A	0.13	0.38	23.47	1.64	0.06	0.00	25.62	4.38	25.68	99.8
G1	0.11	0.26	9.88	1.08	0.06	0.01	11.33	3.60	11.40	99.4
G2	0.10	0.14	6.91	0.37	0.07	0.02	7.52	4.15	7.61	98.8
G3	0.09	0.16	7.11	0.37	0.15	0.06	7.73	4.82	7.94	97.3
G4	0.10	0.11	7.19	0.37	0.05	0.01	7.77	3.01	7.83	99.2
G5	0.10	0.20	7.74	0.62	0.13	0.05	8.66	5.54	8.84	98.0
Profile 3 – Mollic Gleysol – bottom										
A	0.19	0.59	32.67	2.13	0.08	0.00	35.58	3.87	35.66	99.8
Ag	0.14	0.40	15.46	1.05	0.09	0.01	17.05	4.85	17.15	99.4
G	0.15	0.15	18.42	0.83	0.00	0.00	19.55	0.36	19.55	100.0
Profile 4 – Dystric Cambisol - slope										
A	0.13	0.39	1.51	0.11	1.85	2.14	2.14	9.14	6.13	35.0
Bw	0.10	0.15	4.02	0.45	0.65	0.79	4.72	3.68	6.16	76.6
Cg1	0.20	0.27	10.59	1.44	0.06	0.00	12.5	1.48	12.56	99.5
Cg2	0.19	0.23	15.25	0.49	0.00	0.00	16.16	0.67	16.16	100.0
2Ccag	0.20	0.20	26.92	0.17	0.00	0.00	27.49	0.53	27.49	100.0
Profile 5 – Colluvic Regosol - slope										
$A_{del.}$	0.08	0.25	0.51	0.08	2.61	3.27	0.92	8.99	6.80	13.4
ABw_{del}	0.07	0.15	0.42	0.12	3.05	3.92	0.76	8.39	7.73	9.9
C	0.09	0.20	3.13	0.84	2.01	2.61	4.26	5.38	8.88	48.0
Profile 6 – Stagnic Dystric Cambisol – high plain										
A	0.10	0.16	0.47	0.09	4.31	5.37	0.82	15.04	10.50	7.8
Bw	0.10	0.15	0.00	0.00	6.14	5.43	0.25	10.80	11.82	2.2
Cg1	0.13	0.13	1.18	0.34	3.02	3.94	1.78	6.91	8.74	20.3
Cg2	0.39	0.48	3.66	3.50	8.03	6.07	8.03	13.44	22.13	36.3
Cg3	0.76	0.64	10.22	5.41	2.21	2.79	17.03	7.55	22.03	77.3

Soils in the bottom of the valley, in general, more effectively buffered alkali than acids. The buffering areas of alkali ranged from 25.08 to 50.21 cm^2, except G horizon in the profile of Mollic Gleysol (3.05 cm^2). The buffering areas of acids ranged from 13.35 to 43.31 cm^2 (Table 4).

TABLE 4. BUFFER AREAS OF ALKALI (P_{NAOH}) AND ACIDS (P_{HCL}) IN THE SOILS

Horizon	P_{NaOH} (cm^2)	P_{HCl} (cm^2)	P_{NaOH}/P_{HCl}
Profile 1 – Colluvic Gleysol – bottom			
A	48.73	19.73	2.47
AG	41.85	25.88	1.62
G1	50.21	17.91	2.80
G2	37.83	15.84	2.39
G3	45.59	19.17	2.38
Profile 2 – Colluvic Gleysol – bottom			
A	38.91	27.44	1.42
G1	31.60	17.03	1.86
G2	35.31	13.59	2.60
G3	35.72	13.35	2.68
G4	25.08	16.47	1.52
G5	39.90	16.15	2.47
Profile 3 – Mollic Gleysol – bottom			
A	38.06	33.20	1.15
Ag	40.14	21.43	1.87
G	3.14	43.31	0.07
Profile 4 – Dystric Cambisol - slope			
A	49.96	6.32	7.91
Bw	29.03	8.01	3.62
Cg1	13.26	15.18	0.87
Cg2	9.85	25.57	0.39
2Ccag	3.05	40.55	0.08
Profile 5 – Colluvic Regosol - slope			
$A_{del.}$	43.27	5.14	8.42
ABw_{del}	44.30	6.41	6.91
C	31.40	6.28	5.00
Profile 6 – Stagnic Dystric Cambisol – high plain			
A	60.57	8.06	7.51
Bw	56.18	7.34	7.65
Cg1	42.85	5.30	8.08
Cg2	57.76	9.88	5.85
Cg3	48.95	11.52	4.25

DISCUSSION

The sorptive and buffer properties of the soils are being shaped by the properties of the parent material and the overlapping processes of weathering and pedogenesis [1, 5, 6, 8, 9, 11, 12, 19, 21, 22, 23, 24, 27, 28]. The texture, the degree of weathering of the parent material, the mineralogical composition of clay, the content and degree of humification of soil organic matter are the most important factors affecting cation exchange capacity of the soils. These factors determined specific surface area of the solid phase which influence sorption processes. In the examined soils specific surface area ranged from 22.5 to 88.3 m^2 g^{-1}, with maximum in rich in clay parent material of the soils of the high plain and in rich in humus soils of the valley bottom. However, taking into account the content of humus in Colluvic Gleysols and Mollic Gleysols, the resultingvalues of specific surface area were not large. This may be due to a small degree of humification of soil organic matter under conditions of permanent water excess.

CEC of the examined soils was positively related to the content of clay and organic matter (Table 5, 6). Vertical variability of CEC was found in Stagnic Dystric Cambisols of the high plain which referred to the texture of particular horizons. The resulting values of CEC (8.74 do 22.12 cmol(+) kg^{-1}) in the soils were comparable to the ones found in Cambisols and Luvisols of Siedlce Upland [11], Luvisols in the area of Southern Pomeranian Lakeland and higher in relation to the eroded Luvisols of Lublin Upland [23]. Low sorption capacity found in horizons A, Bw and Cg1 of the soils due to the erosion and eluviation of clay in the edge zone of the high plain.

TABLE 5. SPEARMAN'S CORRELATION COEFFICIENTS BETWEEN CEC, BUFFERING AREAS AND SOME PROPERTIES OF THE SOILS OF HIGH PLAIN AND SLOPES ($p<0,05$; n=11; IN BOLD CORRELATIONS STATISTICALLY SIGNIFICANT)

Soil properties	Clay content	Organic matter content	Specific surface area	Hh	CEC
CEC	0.456	0.037	0.488	–	–
P_{NaOH}	-0.187	0.618	0.532	**0.955**	0.756
P_{HCl}	0.688	-0.036	0.689	0.104	0.431

Colluviums on the slopes and in the bottom of the valley differed from the material of the high plain in terms of textural features containing more sand and less clay. In the soils on slopes this reflected in low values of CEC. High CEC found in the soils of the valley bottom is related to the considerable content of organic matter which is confirmed by high, statistically significant, positive correlation coefficient (Table 6). The important role of the component in the shaping of sorptive properties of the soils has been proved many times [9, 24, 27].

TABLE 6. SPEARMAN'S CORRELATION COEFFICIENTS BETWEEN CEC, BUFFERING AREAS AND SOME PROPERTIES OF THE SOILS OF THE BOTTOM OF EROSIONAL-DENUDATIONAL VALLEY ($p<0,05$; $n=11$; IN BOLD CORRELATIONS STATISTICALLY SIGNIFICANT)

Soil properties	Clay content	Organic matter content	Specific surface area	Hh	CEC
CEC	0.454	**0.874**	**0.773**	–	–
P_{NaOH}	0.233	**0.762**	**0.682**	0.593	-0.290
P_{HCl}	0.341	**0.839**	**0.688**	0.181	**0.742**

Ionic composition of soil sorption complex of the soils of the examined valley was varied in space. Acidic cations dominated in Stagnic Dystric Cambisols of the high plain, whose share decreased with depth. The resulting gradual increase of the basis can be a result of the capillary suction of groundwater. Almost full saturation of soil sorption complex with bases was found in the soils of the valley bottom which were under a permanent impact of water. Under the influence of the groundwater, ionic composition of sorption complex changed in acidic sediments eroded from high plain. Calcium, which was the basic base cation in the groundwater, has also become a major component of soil sorption complex in the soils of the valley bottom.

A complex of physical, chemical, sorptive and biological properties of the soils determine their buffer properties. The content of calcium carbonate, pH, CEC and ionic composition of soil sorption complex, the content of clay, the content and the properties of organic matter are the most important factors [16, 17, 20, 24, 25, 26, 33]. The soils of the examined valley were spatially varied in terms of these properties. It which was reflected in the possibilities of buffering of acids and alkali. Acid and rich in clay soils of the high plain were characterized by high buffer capacity of alkali and much lower of acids. The ratio P_{NaOH}/P_{HCl} in the soils ranged from 4.25 to 8.08. Similar regularities were found in the soils of the slopes build of hollow sediments. Buffer areas of alkali in the soils were significantly positively related only with Hh. There were no found statistically significant correlations with the content of clay and organic matter, specific surface area and CEC (Table 5). Glacial till had large possibilities of the buffering of acids which resulted from the presence of carbonates. The soils of the valley bottom, in relation to the soils of the high plain and the slopes, had lower possibilities of the buffering of alkali and much more of acids.

Buffer areas both of acids and alkali were significantly related to the content of organic matter and specific surface area. P_{HCl} was also positively related to CEC. Organic matter was the main factor which determined high buffer capacity of alkali in the soils of the valley bottom. Ion-exchange buffer was an effective mechanism of the neutralization of acids. Similar regularities were found in the soils of spring niches in the valley of the Jarosławianka River, a few kilometers from the examined erosional-denudational valley [9].

CONCLUSIONS

1. The properties of the parent material of the soils of the high plain, water as causative agent of erosion and ion carrier and the quantity and quality of organic matter were the most important factors which determined spatial variability of sorptive and buffer properties of the soils of the examined erosional-denudational valley.

2. Formed of silt-clay hollow sediments Stagnic Dystric Cambisols of the high plain were characterized by vertically differentiated cation exchange capacity which was low in A, Bw and Cg1 horizons and much higher in Cg2 and Cg3 horizons. Acidic cations dominated in sorption complex of the soils, but their share decreased with depth as a result of capillary suction of groundwater. The soils of the high plain had large buffering capacity of alkali and low of acids.

3. Colluvic Regeosols on the slopes had lower sorption capacity and lower buffer capacity of alkali and acids in relation to the soils of the high plain. It is an effect of the transformation of the material during its transport along the slopes (loss of the part of clay fraction) and lower content of humus.

4. Colluvic Gleysols and Mollic Gleysols in the bottom of the valley were spatially and vertically varied in terms of cation exchange capacity which was positively related to the content of organic matter. Permanent supplying with relatively rich in basic cations water resulted in a very high saturation of soil sorption complex with basis. Their share was higher than 97.3%. Calcium dominated in basis. Saturated with base cations soil sorption complex became an effective mechanism of acid neutralization.

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WPŁYW CZYNNIKÓW LITO-MORFOGENETYCZNYCH, HYDROLOGICZNYCH I ANTROPOGENICZNYCH NA WŁAŚCIWOŚCI SORPCYJNE I BUFOROWE GLEB DOLIN EROZYJNO-DENUDACYJNYCH: STUDIUM PRZYPADKU Z OBSZARU RÓWNINY SŁAWIEŃSKIEJ

Celem badań była próba oceny roli różnych czynników w kształtowaniu przestrzennego zróżnicowania właściwości sorpcyjnych i buforowych gleb doliny erozyjno-denudacyjnej wciętej w osady zastoiskowe i zwałowe Równiny Sławieńskiej. Wytypowana do badań dolina jest wycięta w silnie kwaśnych plejstoceńskich utworach zastoiskowych o miąższości około 5 m zalegających na silnie zbitej, węglanowej glinie zwałowej. Dno doliny w jej dolnym i środkowym odcinku jest wypełnione osadami stokowymi o miąższości przekraczającej 4 m, których spąg został wydatowany na 590±55 lat BP. Procesy erozji i akumulacji osadów zostały zainicjowane wskutek wylesienia zlewni w średniowieczu. Współcześnie dolina jest porośnięta bukiem w zróżnicowanym wieku, a jej zlewnia użytkowana rolniczo i zmeliorowana. Wzdłuż stoków doliny wysiąka woda gruntowa, która powoduje zabagnienie jej dna.

Właściwości sorpcyjne i buforowe gleb badanej doliny były zróżnicowane przestrzennie. W ich kształtowaniu podstawową rolę odgrywały właściwości materiału macierzystego gleb, woda, jako czynnik sprawczy erozji i nośnik jonów, roślinność, jako źródło szczątków organicznych, oraz człowiek poprzez wpływ na intensywność procesów erozji i gospodarkę wodna w obrębie zlewni. Powstałe z silnie kwaśnych, pylasto-ilastych utworów zastoiskowych gleby brunatne dystroficzne wysoczyzny charakteryzowały się pojemnością sorpcyjną w zakresie od 8.74–22.12 cmol(+) kg^{-1}. W ich kompleksie sorpcyjnym dominowały kationy H^+ i Al^{3+}, których udział malał wraz z głębokością. Gleby deluwialne związane z wklęsłymi fragmentami stoków charakteryzowały się mniejszą pojemnością sorpcyjną niż gleby wysoczyzny, co należy wiązać z mniejszą zawartością w nich iłu i materii organicznej. Gleby deluwialne oraz torfiasto-glejowe dna doliny miały pojemność sorpcyjną od 7.21–25.68 cmol(+) kg^{-1}. Była ona istotnie dodatnio skorelowana z zawartością materii organicznej i iłu. Wysokie wysycenie kompleksu sorpcyjnego tych gleb kationami zasadowymi (97.2–100.0%) było efektem wpływu wód zasilających. Wśród kationów zasadowych dominował wapń. Kwaśne gleby wysoczyzny oraz stoków miały duże zdolności buforowania zasad i niewielkie kwasów. Większe zdolności buforowania kwasów obserwowane w glebach dna doliny były efektem prawie całkowitego wysycenia ich kompleksu sorpcyjnego kationami zasadowymi. Dużymi zdolnościami buforowania względem kwasów i znikomymi względem zasad charakteryzowała się zalegająca pod utworami zastoiskowymi glina zwałowa.