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POŁUDNIOWOPODLASKA LOWLAND ECOSYSTEM SOIL BUFFER CAPACITY

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ABSTRACT

The paper presents the results of research on soil buffer capacity in Południowopodlaska Lowland ecosystems. The buffer curves were sketched and soil buffer areas measured with planimeter. The data obtained were compared with some soil physical and chemical properties using statistical methods. The greatest acid buffer capacity was observed in highly base-saturated meadow ecosystem soils (V_{CEB} = 82.8 - 98.7%), while the greatest alkali buffer capacity – low base-saturated soils of forest ecosystems (V_{CEB} = 10.8 - 49.5%). Upper horizons of arable land soils showed a greater alkali rather than acid buffer capacity, while soil buffer capacity of deeper mineral horizons changed with soil physical and chemical properties.

Key words: arable land soils, forest soils, meadow soils, buffer capacity, soil physical and chemical properties

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INTRODUCTION

Soil excessive acidification is most responsible for chemical deterioration of soil environment in Poland, affecting physical, chemical and biological soil properties [4,15]. The acidification results in increased base cations leaching deep into the soil profile, toxic aluminium and manganese emergence, increased heavy metal phytotoxicity and decreased fertilisation effect, which deteriorates the yield quantity and, especially, quality [4].

Soil acid deterioration in Poland is greater with years due to air pollution, increased mineral and decreased organic fertilisation, storage of acid waste on soil surface, rainfall effect and insufficient arable land liming and scarce forest soil liming [4,15]. The analysis of acid and alkali soil buffer capacity helps to define the rate and extent of soil chemical deterioration [1,5,6,9,10,12,13,14].

The Południowopodlaska Lowland, a part of the so-called Green Lungs of Poland, is a macro-region whose environment has been well preserved; a typical agricultural land where emission of SO_2 and NO_x remains low [2,3]. Acid and highly acid soils account for 80% of the Południowopodlaska Lowland [15], much affected by the parent rock origin as well as the climate, forest species composition and agricultural practices. Today the soil acidity in the region is intensified by mineral fertilisers and acid rains, which can be due to pollution mainly from south-western Poland.

Assuming that soil shows some resistance to destructive environmental factors, e.g. inflicting soil pH, the research was launched to define the buffer capacity of soil in Południowo-podlaska Lowland different ecosystems as well as the physical and chemical properties affecting the buffer capacity.

MATERIAL AND METHODS

The research covered ten soil profiles to represent varied soil types and subtypes: typical lessive soils (profile 1 and 7), pseudogley lessive soils (2,8), leached brown soil (3), proper black earth (4,5), mineral-and-muck soils (6), podzolic-and-rusty soils (9), deluvial humic soils (10) in the ecosystems of farmland, meadows and forests of the Południowopodlaska Lowland. Soil was sampled in September 1997 and 1998. According to the Central Statistical Office (GUS) data [2,3] (Table 1), the rainfall pH was always less than 5.0 – below the minimum value of natural rainfall acidity [7]. Annual mean rainfall pH over 1995 - 1998 at Jaczewo control station (Południowopodlaska Lowland) ranged from 4.30 - 4.62, while the annual rainfall from 557.6 to 718.0 mm [2].

Soil samples (1 kg) were taken from selected horizons and subhorizons of the soil profiles researched and dried under laboratory conditions. Samples from raw humus subhorizons were ground while samples from the mineral horizon were crushed in a mortar and sieved through 1mm sieve.

Table 1. Weather conditions over 1997-1998 in the region researched

Months												Years	
I	II	II	IV	V	VI	VII	VII	IX	X	XI	XII	1997	1998
Rainfall, mm													
4.4	22,7	36.1	35.5	33.4	59.1	248.7	19.1	38.9	49.9	43.4	25.2	616.4	
27.1	42.1	39.3	66.5	59.5	133.0	71.5	111.3	32.6	69.4	43.4	22.3		718.0

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Number of days with daily rainfall > 0.1mm													
16	19	12	15	14	13	20	6	11	23	20	23	192	
17	15	17	14	7	17	20	18	8	20	20	20		193
pH													
3.78	4.24	4.49	4.67	4.70	4.53	4.97	4.53	4.72	4.37	4.58	4.28	4.62	
4.35	4.55	4.43	4.67	4.74	4.72	4.63	4.62	4.93	4.73	4.33	4.22		4.59
SO_4^{-2} - S, mg·dm^{-3}													
4.06	1.06	1.31	1.43	1.02	0.85	0.44	1.47	1.17	1.08	1.28	0.83	0.87	
1.01	0.93	0.94	1.19	0.65	0.86	1.08	0.92	0.35	0.45	0.89	0.84		0.87
NO_3 – N, mg·dm^{-3}													
2.51	0.89	0.81	0.74	0.52	0.31	0.17	0.56	0.44	0.62	0.50	0.59	0.42	
0.61	0.76	0.78	0.56	0.33	0.31	0.43	0.38	0.19	0.32	0.66	0.72		0.45

Buffer curves were drawn according to Arrhenius with Brenner and Kappen modification [11] adding increasing amounts of 0.1mol HCl·dm^{-3} and 0.1mol NaOH·dm^{-3} to the soil, which after 24h was followed by solution pH measurement. Areas between standard curve and buffer curves drawn for particular genetic horizons were measured with the planimeter. Similarly there were defined the grain size composition according to Bouyoucos method with Casagrande and Prószyński modifications, percentage of carbon in organic compounds - the Tiurin method, hydrolytic acidity (Hh) - with the Kappen method, exchangeable bases (CEB) - in 1 mol CH_3COONH_4·dm^{-3}, pH = 7, and in carbonate horizons in 1 mol NH_4Cl·dm^{-3} [11].

Cation exchange capacity (CEC) was calculated using the following equation: CEC = CEB + Hh, the degree of base saturation of soil sorption complex with $\%V_{CEB}$= CEB·100/CEC and the degree of hydrogen saturation of soil sorption complex was defined with $\%V_{Hh}$ = Hh·100/CEC.

Soil buffer area linear correlation coefficients and physical and chemical soil properties were calculated using the following equation [16]:

$$r = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2 \sum_{i=1}^{n}(y_i - \overline{y})^2}} = \frac{\operatorname{cov} x, y}{\sqrt{\operatorname{var} x \cdot \operatorname{var} y}};$$

where:

n – number of pairs of observations (x_i, y_i),
x_i – value of independent variable,
x – arithmetic variable x mean
y_i – value of dependent variable,
y – arithmetic variable y mean.

The correlation coefficient value significance was determined for $p \leq 0.01$ and $p \leq 0.05$ and degrees of freedom for v = n-2.

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RESULTS

The soils researched varied in their physical and chemical properties. The soils originated from Riss sands, dust and clay contained from 4 to 49% of < 0.02 mm particles and from 2 to 24% of colloidal clay fractions (< 0.002 mm) (Table 2).

Table 2. Soil grain size composition

Profile no. Position	Genetic horizon	Depth, cm	Share of fraction, %			
			1- 0.1 mm in diameter	0.1- 0.02 mm in diameter	< 0.02 mm in diameter	< 0.002 mm in diameter
1 Mokobody	Ap	0-32	62	24	14	3
	AEet	32-40	62	23	15	4
	Eet	40-65	70	18	12	3
	EetBt	65-85	55	20	25	10
	Bt	85-110	46	19	35	21
	C	>110	39	24	37	24
2 Lipiny	Ap	0-25	55	31	14	4
	AEet	25-40	53	34	13	3
	Eet	40-57	38	47	15	3
	IIBtg	57-100	40	31	29	16
	IICg	>100	38	28	33	20
3 Gołaszyn	Ap	0-30	60	25	14	6
	Bbr	30-48	56	28	16	7
	C	>48	48	38	14	6
4 Cierpigórz	Aa	0-8	35	36	29	11
	Aa	8-42	34	35	31	9
	Ccagg	42-98	41	33	26	7
	II Ccagg	>98	78	12	10	2
5 Siedlce	Aa	0-10	69	16	15	7
	Aa	10-39	17	15	14	6
	ACcagg	39-64	74	14	12	5
	Ccagg	64-100	83	6	11	4
	Gca	>100	57	17	26	10
6 Zakrze	AOM	0-25	47	29	24	12
	D1G	25-60	26	47	27	13
	D2G	>60	81	12	7	2

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7 Stok Lacki	Ol	0-2	0	0	0	0
	Ah	2-9	52	32	16	6
	AEet	9-29	57	25	18	5
	Eet	29-50	54	25	21	5
	Bt	50-92	47	22	31	18
	C	>92	39	26	35	24
8 Niemojki	Ol	0-3	0	0	0	0
	Ah	3-15	43	41	16	6
	AEet	15-31	42	42	16	5
	Eet	31-56	39	44	17	5
	IIBtg	56-101	38	39	23	14
	IICg	>101	35	32	33	20
9 Gostchorz	Ol	0-2	0	0	0	0
	Ofh	2-6	0	0	0	0
	AEes	6-18	79	13	8	2
	BfeBv	18-48	82	10	8	2
	BvC	48-56	91	5	4	2
	C1	56-86	93	3	4	2
	C2	>86	90	6	4	2
10 Konstantynów	Ol	0-1	0	0	0	0
	Aa	1-9	5	46	49	14
	Aa	9-39	9	46	45	12
	AC	39-118	19	52	29	10
	C1	118-139	31	51	18	7
	C2	>139	38	41	21	14

The soil pH ranged from highly acidic to alkaline (pH_{KCl} = 3.19 - 7.45); meadow soil pH - from 6.04 to 7.45, arable land soil pH - from 4.25 to 6.43, while the lowest reaction (pH from 3.19 to 5.20) was recorded for forest soils (Table 3).

Table 3. Soil physical and chemical properties

Profile no.	Genetic horizon	pH in		Organic C, %	$CaCO_3$, %
		H_2O	KCl		
1	Ap	5.42	4.72	0.71	0.0
	AEet	4.93	4.25	0.20	0.0
	Eet	5.24	4.55	0.09	0.0
	EetBt	6.23	5.10	0.11	0.0
	Bt	6.61	5.44	0.18	0.0
	C	6.44	5.10	0.14	0.0

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2	Ap	5.83	4.85	0.97	0.0
	AEet	5.34	4.46	0.31	0.0
	Eet	5.62	4.66	0.11	0.0
	IIBtg	6.03	4.89	0.15	0.0
	IICg	6.21	4.95	0.12	0.0
3	Ap	6.70	5.51	0.79	0.0
	Bbr	6.75	5.62	0.28	0.0
	C	7.02	6.43	0.12	0.0
4	Aa	6.88	6.10	3.68	0.0
	Aa	6.92	6.04	2.92	0.0
	Ccagg	7.64	7.23	0.33	2.6
	II Ccagg	8.00	7.34	0.23	3.7
5	Aa	7.12	6.73	3.17	0.0
	Aa	7.21	6.90	2.51	0.0
	ACcagg	7.43	7.02	0.96	2.1
	Ccagg	7.24	7.24	0.26	2.5
	Gca	7.82	7.45	0.18	4.2
6	AOM	7.25	6.94	5.92	0.0
	D1G	7.36	7.10	0.20	0.0
	D2G	7.12	6.65	0.06	0.0
7	Ol	4.44	3.48	3.37	0.0
	Ah	4.23	3.40	2.39	0.0
	AEet	4.02	3.80	0.60	0.0
	Eet	4.33	3.80	0.24	0.0
	Bt	4.42	3.90	0.14	0.0
	C	4.51	3.90	0.14	0.0
8	Ol	4.52	3.98	35.3	0.0
	Ah	4.12	3.63	0.96	0.0
	AEet	4.24	4.05	0.55	0.0
	Eet	4.31	4.16	0.24	0.0
	IIBtg	4.52	3.60	0.11	0.0
	IICg	4.71	3.70	0.10	0.0
9	Ol	3.91	3.52	48.2	0.0
	Ofh	3.62	3.19	39.1	0.0
	AEes	3.83	3.27	1.14	0.0
	BfeBv	4.24	4.09	0.30	0.0
	BvC	4.41	4.16	0.05	0.0

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	C1	4.54	4.10	0.03	0.0
	C2	6.34	5.20	0.08	0.0
10	Ol	4.82	4.41	31.12	0.0
	Aa	4.53	4.12	5.46	0.0
	Aa	4.61	4.13	4.08	0.0
	AC	4.72	4.21	1.15	0.0
	C1	4.53	4.11	0.54	0.0
	C2	4.35	3.94	0.33	0.0

The organic C content in mineral-and-organic horizons of the soils researched ranged from 0.71% to 5.29%. The highest percentage of compound organic C, from 31.1% to 48.2%, was noted in forest soil organic horizons (profiles 7, 8, 9, 10). The cation exchange capacity of the soil researched (Table 4)

Table 4. Sorption properties and buffer area of investigated soils

No.	Genetic horizons	Depth, cm	mmol(+)·kg^{-1}			% V_{CEB}	% V_{Hh}	cm^2	
			CEB	Hh	CEC			P_{NaOH}	P_{HCl}
1	Ap	0 – 32	31.0	28.7	59.7	51.9	48.1	11.6	5.6
	AEet	32 – 40	25.3	24.2	49.5	51.1	48.9	9.8	3.7
	Eet	40 – 65	21.0	9.8	30.8	62.8	31.8	6.8	3.2
	EetBt	65 – 85	96.0	11.6	107.6	89.2	10.8	6.3	7.2
	Bt	85 – 110	127.2	12.4	139.6	91.1	8.9	7.4	10.3
	C	>110	148.0	14.8	162.8	90.9	9.1	8.6	10.7
2	Ap	0 – 25	34.0	25.1	59.1	57.5	42.5	13.9	6.8
	AEet	25 – 40	21.1	19.1	40.1	52.4	47.6	9.7	4.8
	Eet	40 – 57	18.0	10.5	28.5	63.2	36.8	7.7	3.9
	IIBtg	57 – 100	84.0	18.4	102.4	82.0	12.0	8.7	7.2
	IICg	>100	124.0	19.1	143.1	86.7	13.3	9.5	8.4
3	Ap	0 – 30	29.5	19.0	48.5	60.8	39.2	10.2	7.2
	Bbr	30 – 48	23.6	9.2	32.8	71.9	28.1	8.2	7.9
	C	>48	27.1	4.2	31.3	86.5	13.5	5.6	8.8
4	Aa	0 – 8	89.3	18.5	107.8	82.8	17.2	9.7	21.5
	Aa	8 – 42	82.6	14.5	97.1	85.1	14.9	9.3	21.0

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	Ccagg	42 – 98	64.5	6.0	70.5	91.5	8.5	6.0	19.4
	IICcagg	>98	28.6	1.0	29.6	96.6	3.4	1.5	15.1
5	Aa	0 –10	74.2	8.8	83.0	89.4	10.6	7.9	22.4
	Aa	10 - 39	65.1	6.6	71.7	90.8	9.2	7.4	21.5
	ACcagg	39 – 64	38.8	3.3	42.1	92.2	7.8	4.5	16.4
	Ccagg	64 – 100	31.3	2.0	33.3	94.0	6.0	2.5	14.8
	Gca	>100	89.0	1.2	90.2	98.7	1.3	2.2	23.6
6	AOM	0 – 25	245.0	27.0	272.0	90.1	9.9	8.4	23.4
	D1G	25 – 60	62.5	7.7	70.2	89.0	11.0	7.3	19.4
	D2G	>60	26.8	4.2	31.0	86.4	13.6	2.1	6.2
7	Ol	0 – 2	nd*	442.1	nd	nd	nd	23.5	6.6
	Ah	2 – 9	27.5	90.0	117.5	23.4	76.6	25.1	5.3
	AEet	9 – 29	18.4	44.3	62.7	29.3	70.7	18.7	4.2
	Eet	29 – 50	16.5	35.0	51.5	32.0	68.0	16.6	3.3
	Bt	50 – 92	47.0	51.0	98.0	47.9	52.1	18.6	6.1
	C	>92	51.0	54.0	105.0	48.6	51.4	18.9	7.1
8	Ol	0 – 3	nd	398.2	nd	nd	nd	18.3	5.5
	Ah	3 – 15	14.4	54.0	68.4	21.1	78.9	19.7	5.1
	AEet	15 – 31	12.5	33.7	46.2	27.1	72.9	13.6	4.0
	Eet	31 – 56	9.4	23.0	32.4	28.9	70.9	10.8	3.0
	IIBtg	56 – 101	18.7	39.3	68.2	42.3	57.7	12.5	5.7
	IICg	>101	23.9	47.5	84.7	43.9	56.1	14.3	6.9
9	Ol	0 – 2	nd	541.0	nd	nd	nd	27.5	3.7
	Ofh	2- 6	nd	623.1	nd	nd	nd	30.5	2.8
	AEes	6 – 18	7.4	61.7	69.1	10.8	89.2	24.5	2.5
	BfeBv	18 – 48	5.9	31.9	36.8	16.0	84.0	16.6	6.0
	BvC	48 – 56	3.0	15.9	18.9	15.9	84.1	5.1	4.1
	C1	56 – 86	3.5	15.0	18.5	18.9	81.1	3.7	2.8
	C2	>86	12.1	8.1	20.2	59.9	40.1	3.2	4.4

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10	Ol	0 – 1	nd	339.0	nd	nd	nd	20.5	6.9
	Aa	1 – 9	100.0	107.6	207.6	48.2	51.8	22.9	6.6
	Aa	9 – 39	93.4	95.2	188.6	49.5	50.5	21.6	6.0
	AC	39 – 118	45.4	49.0	94.4	48.1	51.9	16.2	5.4
	C1	118 - 139	34.0	32.0	72.0	47.2	52.8	13.5	4.7
	C2	>139	31.0	38.8	69.8	44.4	55.6	12.7	4.2

nd*- non determined
ranged from 18.5 mmol(+)$\cdot$kg^{-1} in loose sand horizon of forest soil to 272.0 mmol(+)$\cdot$kg^{-1} in muck horizon of meadow soil.

The buffer curves drawn for arable land soils were similar in shape but differed in their deviation from the standard curve; the greatest deviation for alkaline pH was shown by humic horizons whose alkaline buffer capacity was 1.4 - 2 times greater than the acid buffer capacity. The greater the depths of arable land soil genetic horizon, the greater the differences in the buffer capacity. Out of all the lessive soil mineral horizons, the lowest alkaline and acid buffer capacities were recorded for Eet horizons whose respective buffer area measurements were: P_{NaOH} = 3.2 - 3.9 cm^2, P_{HCl} = 6.8 - 7.7 cm^2 (Fig. 1, Table 4). Acid and alkaline buffer capacities in illuvial horizon Bt and parent rock C of lessive soils were greater and less diversified than buffer capacities of Eet horizons. As for brown soil, there was recorded a slight increase in the resistance of Bbr and C genetic horizons to acidification (P_{HCl} 7.9 - 8.8 cm^2) and a considerable decrease in their resistance to alkalisation (P_{NaOH} = 8.2 - 5.6 cm^2), which was due to an increase in base saturation of soil sorption complex (V_{CEB} = 60.8 - 86.5%).

Fig. 1. Buffer curves drawn for lessive soil horizons

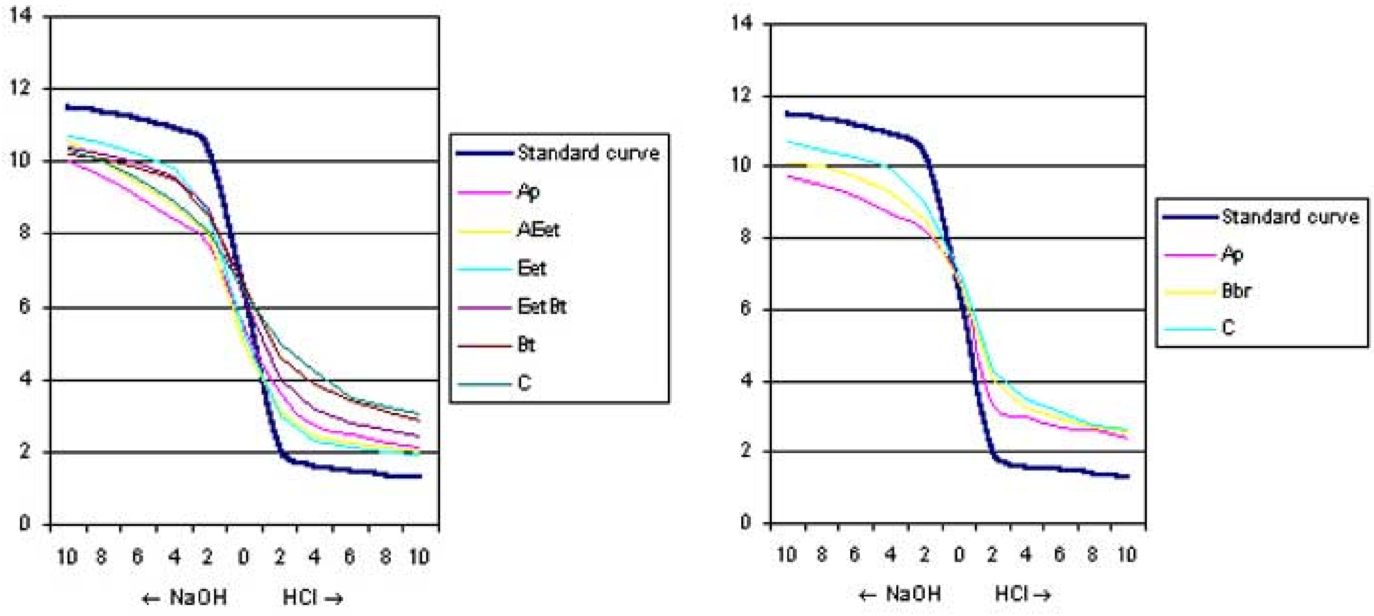

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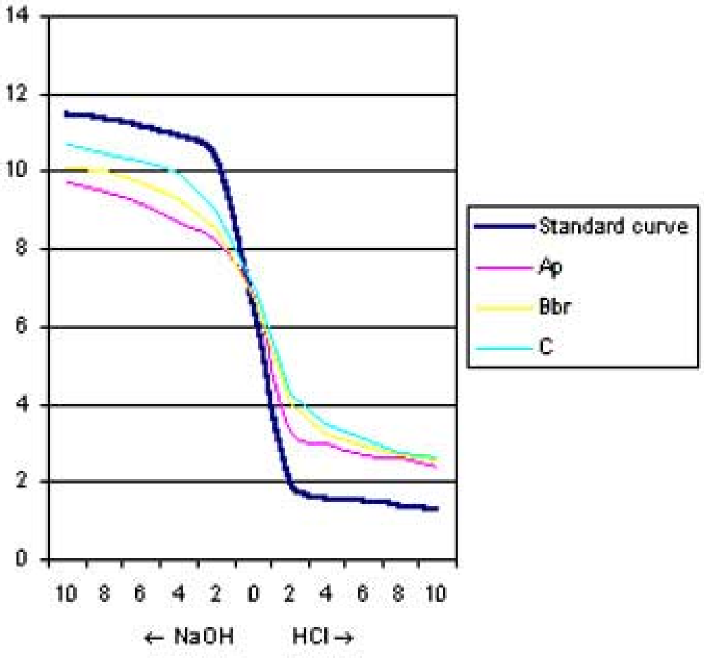
Fig. 2. Buffer curves drawn for brown soil horizons



For all the arable land soils analysed, the greatest increase in pH value as well as the greatest decrease in most genetic horizons were recorded when 2-4 cm^3 of 0.1mol $NaOH \cdot dm^{-3}$ or 0.1 mol $HCl \cdot dm^{-3}$ were added. Any further acidifying or alkalisation caused less considerable pH changes. The highest pH increase up to 10.9 was noted in Eet horizons of lessive soils and parent rock C of brown soil after 10 cm^3 of NaOH was added, while the lowest pH decrease to 1.9 - 2.0 was also noted in Eet horizons (Fig. 1, 2).

The buffer curves drawn for genetic horizons of meadow soils (profiles 4, 5, 6) indicated very high deviation from standard curve for acid pH and much smaller for alkaline pH. The ratio of the above areas ranged from 2.2 in humic horizon A in profile 4 to 15.7 in Gca mineral horizon of marly clay in profile 5 (Table 4). In the meadow soil profiles analysed, generally, the greater the depth of genetic horizon, the smaller the buffer area, ranging from 21.5 - 23.4 cm^2 in humic horizons to 19.4 - 6.2 cm^2 in mineral horizon. Only the buffer area defined for Gca carbonate clay horizon in profile 5 was very large and amounted to 23.6 cm^2. Similar changes were observed for the genetic horizon buffer area for alkaline pH which was much smaller ($P_{NaOH} = 1.5 - 9.7$ cm^2).

Whenever acid was added, the buffer curves drawn for meadow soil humic horizons showed a high soil resistance to acid activity, hence slight pH changes, while deeper mineral horizons showed a considerable pH value decrease (Fig. 3, 4).

Fig. 3. Buffer curves drawn for black earth horizons

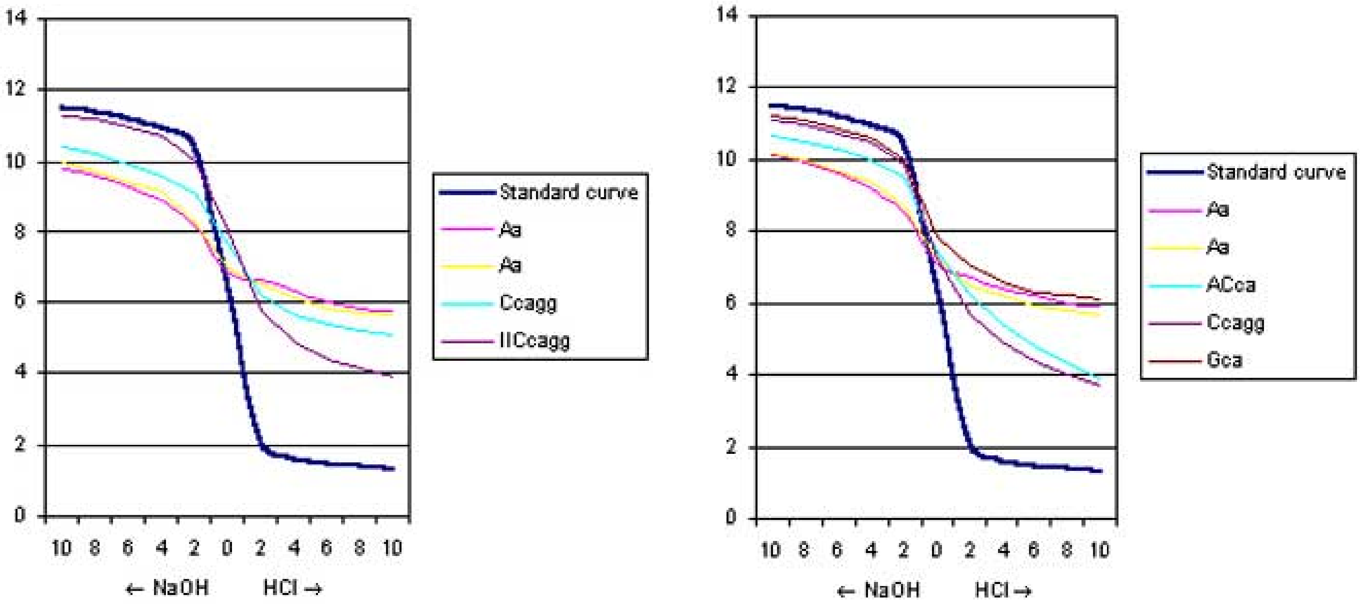
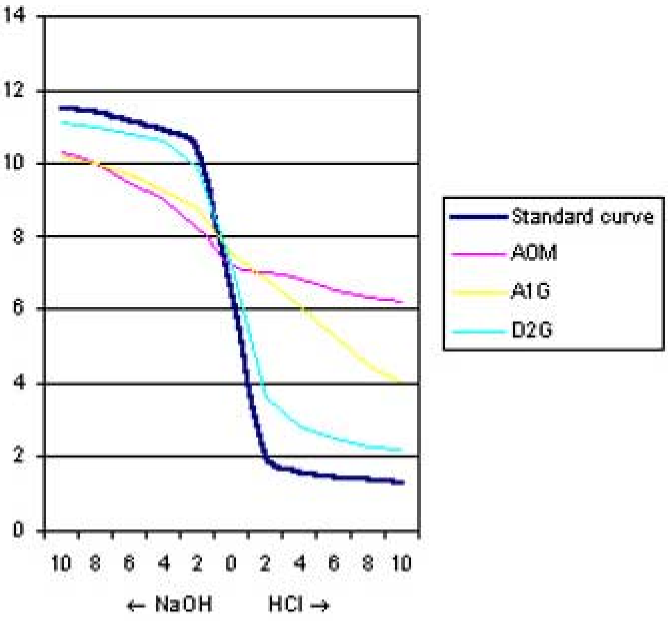


Fig. 4. Buffer curves drawn for mucky soil horizons



The forest soil profiles analysed (profiles 7, 8, 9, 10) were observed to show the greatest resistance to alkalisation in organic as well as mineral-and-organic horizons whose buffer curve slope against the horizontal of the graph was much smaller than the buffer curve slope drawn for deeper mineral horizons (Fig. 5, 6, 7).

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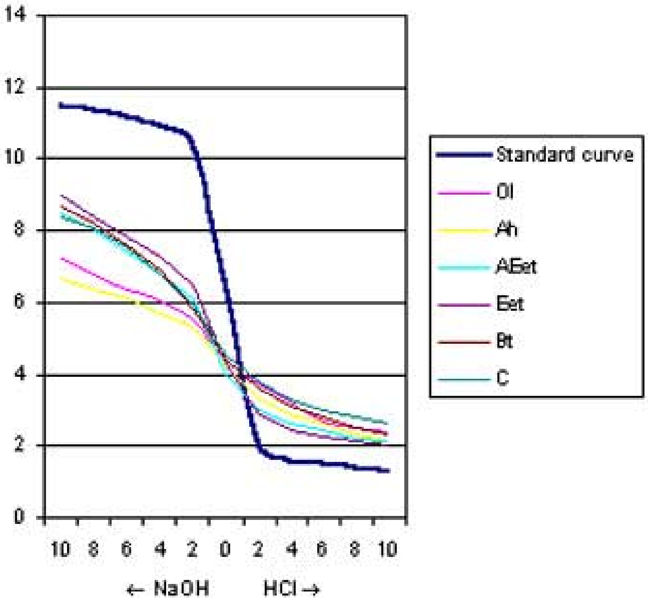
Fig. 5. Buffer curves drawn for forest lessive soil horizons



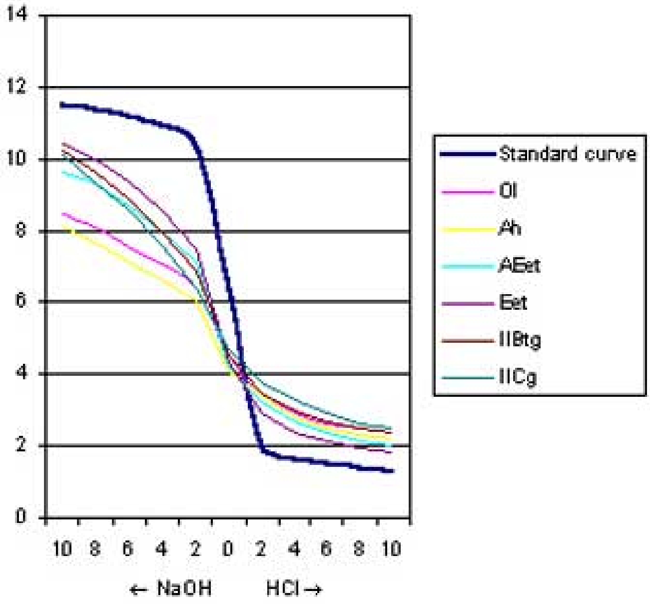
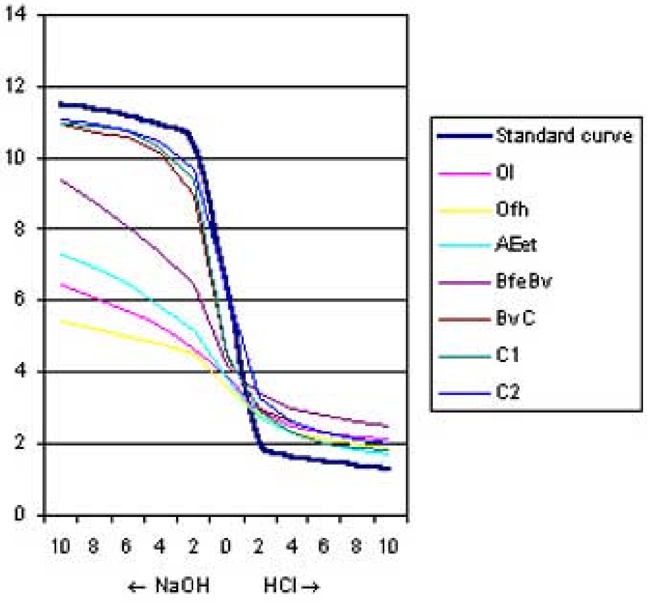
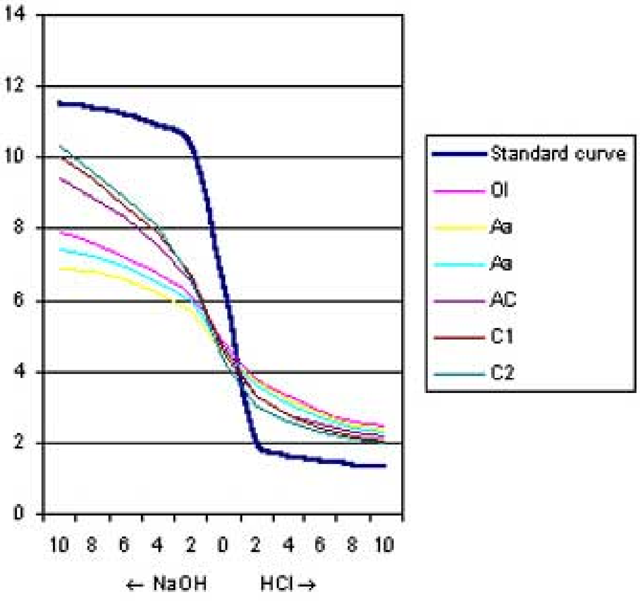


Fig. 6. Buffer curves drawn for rusty

Fig. 7. Buffer curves drawn for deluvial soil horizons soil horizons





In organic and mineral-and-organic forest soil horizons, adding 10 cm^3 of NaOH increased the value of pH up to 5.4 - 8.5, while in mineral horizons it increased up to as much as 11.1. Out of all the forest soils analysed, the greatest alkaline buffer capacity was noted in rusty soil whose buffer areas ranged from 24.5 to 30.5 cm^2. The C content in organic compounds there ranged form 1.14 to 48.23% (Table 3). Mineral horizons C1 and C2 of that profile showed the smallest - 3.2 - 3.7 cm^2 alkaline buffer area. Both horizons represented loose sand grain size composition of a low sorption capacity (CEC=18.5-20.2 $mmol(+)\cdot kg^{-1}$) (Table 4). In forest lessive soils the lowest alkaline buffer capacity was detected in eluvial horizons Eet whose P_{NaOH} buffer areas ranged from 10.8 to 16.6 cm^2. Illuvial horizons Bt and parent rock C showed a greater alkaline buffer capacity, while the P_{NaOH} buffer areas ranged from 12.5 to 18.9 cm^2.

In deluvial humic soils (profile 10) originated from hydro-glacial dust, the genetic horizon resistance to alkaline activity decreased with the depth of soil profile, which was seen from their buffer areas decreasing from 22.9 cm^2 in accumulation horizon Aa to 12.7cm^2 in horizon C2 (Table 4). The greater the depth, the lower cation exchange capacity of genetic horizons (207.6 - 69.8 $mmol(+)\cdot kg^{-1}$), C content in organic compounds (31.12 - 0.33%) and the content of particles <0.02 mm (49 - 18%) (Tables 2,3,4).

Forest soil alkaline buffer capacity was much lower than acid buffer capacity. The smallest acid buffer areas (P_{HCl} 2.5 - 3.3 cm^2) were observed in lessive soil horizons Eet and in rusty soil horizons AhEes. The greatest HCl buffer areas were observed for organic horizons O (P_{HCl} 3.7-7.1 cm^2), for mineral-and-organic horizons Ah, illuvial horizons Bt as well as parent rock C in lessive soils (Table 4).

DISCUSSION

The soil types and their genetic horizons analysed varied in their buffer capacity due to their physical and chemical properties. The statistical analysis showed that the HCl buffer area size was highly significantly and positively correlated with the pH value in H_2O (r = 0.80**), with the pH value in KCl (r = 0.84**), with the exchangeable base sum (r = 0.57**) as well as with the cation exchange capacity (r = 0.32*) and negatively correlated with hydrolytic acidity (r = - 0.40**) (Table 5). The NaOH buffer area was highly significantly and positively correlated with the hydrolytic acidity (r = 0.63**), the C content of organic compounds (r = 0.50**), the cation exchange capacity (r = 0.33*) and with the <0.02 mm particle content (r = 0.36*), and negatively with the pH value in H_2O (r = - 0.76**) as well as with the pH value in KCl (r = - 0.75**).

Table 5. Correlation coefficients between alkaline/acid buffer area and physical and chemical soil properties

Correlation	Number	Correlation coefficient (r)	Significance level (p)
P_{NaOH} – pH in H_2O	51	-0.76	0.01
P_{NaOH} - pH in KCl	51	-0.75	0.01
P_{NaOH} - % organic C	51	0.51	0.01
P_{NaOH} - Hh	51	0.63	0.01
P_{NaOH} - CEC	46	0.33	0.02
P_{NaOH} - % < 0.02 mm	46	0.36	0.02
P_{HCl} - pH in H_2O	51	0.80	0.01
P_{HCl} - pH in KCl	51	0.84	0.01
P_{HCl} - CEB	46	0.61	0.01
P_{HCl}- Hh	51	- 0.43	0.01
P_{HCl} - CEC	46	0.32	0.03

The highest buffer capacity was noted in organic and mineral-and-organic horizons of the soils examined; meadow soils - acid buffer capacity especially, while in upper horizons of arable land and forest soils - alkaline buffer capacity. Humic horizons of meadow soils (black earth and muck soil) showed a very high sorption capacity (CEC = 71.7 - 272.0 mmol(+)$\cdot$kg^{-1}), base saturation (V_{CEB}= 82.8 -90.8%) and high content of carbon in organic compounds (2.51 - 5.92%). In meadow soil horizons rich in $CaCO_3$ the value of P_{NaOH} was low and of P_{HCl} - high. Similar relations were recorded by Miechówka et al. [8] for Podhale soil buffer capacity.

In arable land and forest lessive soil profiles, the lowest alkaline as well as acid buffer capacity was observed in horizon Eet due to lower sorption capacity of these horizons (CEC = 32.4 - 51.5 mmol(+)$\cdot$kg^{-1}) saturated mostly with hydrogen cations (V_{Hh}= 31.8 - 70.9%) and could have been due to decreased richness in some buffer systems.

Out of all the soils analysed, the greatest alkaline buffer capacity was noted for forest soils, yet they showed less resistant to acidification. Buffer curves drawn for the impact of acid on forest soils were rather flat. A considerable change in the curve slope was recorded after adding 2 - 4 cm^3 of 0.1 mol HCl$\cdot$dm^{-3}. A greater amount of acid (up to 10 cm^3) caused slight pH changes up to 2.5 - 2.0 (in some horizons even up to pH 1.7). Similar relations were also recorded by other authors who analysed the course of two buffer curve sections – the so-called pH jump and slow change [5,13,17], which also applies for arable land soils. All that could have been related to the so-called buffer 'threshold' below which the soil reaction is affected by acid aluminium ion extraction from weathering horizons or by acid organic matter extraction from organic and mineral-and-organic horizons where pH value decreased to 2 and below.

Alkaline buffer curves drawn for organic and mineral-and-organic forest soil horizons showed a very high deviation from standard curve, which pointed to a high humus resistance to pH growth and was due to highly unsaturated forest humus where acid cations prevailed (V_{Hh} = 51.8 - 89.2 %). In forest soils hydrogen-and-acidic group bonds as well as exchangeable aluminium could neutralise a considerable number of alkalis, while acid neutralising potential was due to a limited amount of alkaline cations (V_{CEB} = 10.8 - 49.5%). Similar observations were recorded by other authors who researched buffer of soils used differently [9,10,12,13].

Buffer capacity of different soils of varied ecosystems investigated results from soil formation processes, while a varied buffer area in different genetic horizons – from uneven distribution of buffer systems (carbonate, silicate, aluminous, ferric) [17], which was clearly visible in the profiles of the soils examined, especially in lessive arable land and forest soils as well as in rusty forest soil.

CONCLUSIONS

1. Out of all the soils of different Południowopodlaska Lowland ecosystems examined, the greatest resistance to acid activity was recorded for meadow soils and their alkaline buffer capacity was 2 - 10 times lower.
2. The greatest resistance to alkaline activity was noted for forest soils, yet they showed little resistance to acid activity.
3. Upper horizons of arable land soils showed a greater alkali rather than acid buffer capacity, while soil buffer capacity of deeper mineral horizons changed with soil physical and chemical properties.

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4. Buffer capacity of different genetic horizons resulted from soil formation processes.
5. In lessive arable land and forest soil profiles, the lowest alkaline and acid buffer capacities were observed in horizons Eet showing lower exchange cation capacity than in illuvial horizons Bt whose buffer capacity was much higher.
6. The statistical analysis showed that the soil resistance to acid activity defined with correlation coefficient was highly significantly correlated with pH value in KCl and in H_2O, sum of exchangeable bases (SEB), hydrolytic acidity (Hh) and with cation exchange capacity (CEC).
7. The resistance of the soils to alkaline activity was highly significantly correlated with pH in H_2O and in KCl, hydrolytic acidity (Hh), C content of organic compounds, < 0.02 mm particle content and with cation exchange capacity (CEC).

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