Acta Agrophysica, 2001, 50, 59-70

ACIDITY AND BUFFERING PROPERTIES OF SELECTED SOIL TYPES OF THE LASY JANOWSKIE LANDSCAPE PARK

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A b s t r a c t. The aim of this study was to analyse the acidity and buffer abilities of selected soils occurring within terrestrial (forest, arable and meadow) ecosystems, under specific form of protection within the Lasy Janowskie Landscape Park. The results of the study indicate that the very acid and acid reaction of the soil environment is the result of natural processes, such as relations between mother rock and plant cover (low pH, high value of hydrolytic and exchangeable acidity, and high content of mobile aluminum), and low degree of saturation of the sorption complex with bases. The greatest buffering abilities showed typic gley soil *(Dystric Gleysol)*, peat soil *(Terric Histosol)*, and accumulation horizons of other soil types.

K e y w o r d s: buffer properties, terrestrial ecosystems, Lasy Janowskie Landscape Park.

INTRODUCTION

It is well known from the literature of the subject that buffer properties of soils in acidic and alkaline range allow us to estimate not only the susceptibility of soil to chemical degradation, but also its rate and range. On the other hand, soil resistance to reaction changes constitutes one of the most evident prove of its ability to withstand destructive influence of external factors, e.g. acid deposition. This phenomenon is of special importance when sustainability of forest ecosystems in protected areas has to be determined or predicted [1,5,6,11-14,17].

Among many protected areas in the Lublin region, there is one of the greatest forest complexes in Poland, i.e. the Lasy Janowskie Landscape Park. This creates a possibility of evaluating the changes in the natural ecosystem environment and the relations between the state of plant associations and specific features of the soil environment, such as acidity or alkalinity, buffering properties, etc. Moreover, according to literature data [1,6,12,15], it can also be estimated whether soil environment acidification derives from natural factors or from the anthropogenic ones. Therefore, the aim of this study was to analyse the acidity and buffer abilities of selected soils occurring within terrestrial ecosystems under specific form of land protection.

STUDY AREA AND METHODS

The Lasy Janowskie Landscape Park (39150 ha) was established in 1984 (Fig. 1). A high natural value of the Park results from the variability of living nature (202 plant communities were distinguished in there, including 22 forest, 65 aqueous, 17 peat communities, and many species protected according to nature protection regulations, e.g. the Biłgorajski Horse) and geogenic nature (river valleys; sand dunes, bog and pond complexes, mid-forest peat land, and soil mosaic). The region is also interesting in terms of wooden architecture and many historical events, such as partisan battles from the World War II (Porytowe Wzgórze), etc. [5,8,17].

As to the physiography, the Park is situated within the Biłgorajska Plain, a part of the Sandomierska Valley. The area of the Park is a wide plain, elevated 150-230 m a.s.l. The Park is covered mainly with the Quarternary river sands of the Pleistocene accumulation terraces, and with aeolian sands. In some places fluviglacial sands and boulder clay patches can be met. Mean annual air temperature reaches 7.4 ^{o}C, and mean annual precipitation ranges from 600 to 650 mm.

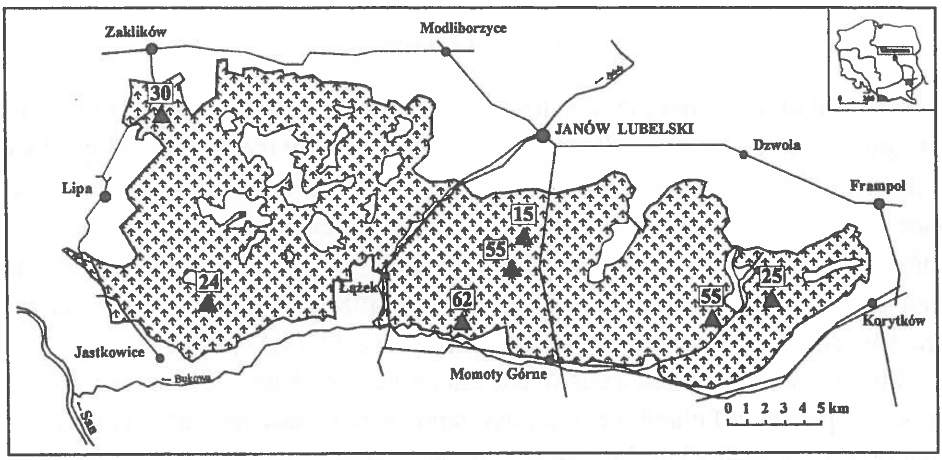

Fig. 1. Location of soil profiles in the Lasy Janowskie Landscape Park.
▲- soil profile studied.

Hydrography of the area is also reach; aqueous bodies occupy 3.3%. Coniferous (pine) and mixed forests predominate within the Park [2-5, 8-10].

The main soil forming factors in the study area were: plant cover, lithology, and water relations. The basic soil formation process was that of podsolization - related to the plant cover, mainly of the pine forest type, as well as mother rock (loose and weakly loamy sands). Important were also water relations and therefore numerous are gleyey, boggy, and post-boggy soils. Podzolic soils occupy almost 69% of the Park, while semihydrogenic and hydrogenic soils constitute 25% [17]. Seven soil units, characteristic for the Lasy Janowskie Landscape Park, were chosen for the investigation. The following properties were analysed in 39 soil samples, taken from individual genetic horizons distinguished: grain size distribution (Casagrande areometric method as modified by Prószyński); total organic C - Tiurin's method; organic matter content by burning in 550 C^{o}; pH in KCl - potentiometrically; hydrolytic acidity - Kappen's method; exchangeable aluminum - Sokolov's method; exchangeable cations 1 M ammonium acetate of pH=7; and buffering properties after Arrhenius method. Basing on the results obtained the buffer curves were plotted, where surfaces between theoretical and a given experimental buffer curve were measured with computer techniques. The results are presented in Tables 1-4 and Figs. 2-3.

RESULTS

The soil units selected for the study were classified as follows: (acc. to "Systematyka Gleb Polski [16] and the "FAO-UNESCO Revised Legend" [7]) (Tables 1-2):

I. Typic gley soil (*Dystric Gleysol*), derived from loose sand, 150-year-old spruce-fir forest - profile 15;
II. Podzolized brown acid soil (*Cambic Podzol*), derived from weakly loamy sand on strong loamy sand, 55-year-old oak forest - profile 24;
III. Typic podzol soil (*Haplic Podzol*), derived from loose river sands, 30-year-old pine forest - profile 25;
IV. Podzolized rusty soil (*Cambic Arenosol*), derived from weakly loamy aeolian sand, fresh forest - profile 30;
V. Typic river alluvial soil (*Eutric Fluvisol*), derived from light loam, meadow - profile 54;
VI. Degraded (gray) black earth (*Gleyic Phaeozem*) derived from weakly loamy sand on light loam, arable land - profile 55;
VII. Peat soil (*Terric Histosol*), derived from medium deep peat, mixed forest - profile 62.

Table 1. Grain size distribution of selected soil types in the Lasy Janowskie Landscape Park (see also [5] and [17])

Profile No.	Genetic horizon PTG (1989)	Genetic horizon FAO-UNESCO Revised Legend (1997)	Depth (cm)	Grain size (mm) distribution in % >1	1.0-0.1	0.1-0.02	<0.02	<0.002
15			Typic Gley Soil (*Distric Gleysol*)					
	O	O	4-0	n.d.	n.d.	n.d.	n.d.	n.d.
	A	A	1-7	2	64.8	31.2	4	1
	G1	Cg1	20-30	3	70.8	27.2	2	1
	G2	Cg2	50-60	12	66.8	31.2	2	2
24			Podzolized Brown Acid Soil (*Cambic Podzol*)					
	O	O	4-0	n.d.	n.d.	n.d.	n.d.	n.d.
	A	A	0-4	0	57.0	33.0	10	2
	AE	AE	10-20	4	63.5	26.5	10	3
	B(fe,br)C	BC	28-38	4	61.8	28.2	10	3
	IIC	2C	45-55	2	42.0	23.0	35	21
	IIIC	3C	80-90	2	71.3	24.7	4	3
25			Typic Podzol Soil (*Haplic Podzol*)					
	O	O	0-7	n.d.	n.d.	n.d.	n.d.	n.d.
	A	A	5-15	0	76.7	20.3	3	2
	Ees	E	15-25	0	85.8	11.2	3	2
	Box	Bsm	31-40	0	79.6	16.4	4	2
	Bfe	Bs	50-60	0	83.6	14.4	2	1
	C1	C1	70-80	0	89.4	8.6	2	1
	C2	C2	130-140	0	76.7	20.3	3	2
30			Podzolized Rusty Soil (*Cambic Arenosol*)					
	O	O	0-3	n.d.	n.d.	n.d.	n.d.	n.d.
	AEes	AE	5-15	0	82.6	5.4	12	5
	Bfe	Bs	18-27	0	77.7	14.3	8	4
	Bv	Bw	30-40	1.3	80.3	12.7	7	4
	BvC	BC	50-60	0	92.0	2.0	6	3
	C	C	115-125	0	93.0	2.0	5	2
54			Typic River Alluvial Soil (*Eutric Fluvisol*)					
	A1	A1	2-10	0	36.0	54.0	10	0
	A2	A2	14-20	0	38.0	48.0	13	2
	C	C	25-35	0	40.3	46.7	13	0
	Cgg	Cg	50-60	0	63.3	29.7	7	1
	IIC1gg	2Cg1	76-80	0	14.0	55.0	31	18
	IIC2gg	2Cg2	81-86	0	8.3	69.7	22	13
	IIC3gg	2Cg3	87-97	0	23.8	58.2	18	9
55			Degraded (Gray) Black Earth (*Gleyic Phaeozem*)					
	Ap	Ap	5-15	0	66.0	26.0	8	0
	A	A	18-28	2	65.5	27.5	7	0
	C	C	35-45	1	46.5	39.5	14	3
	IICgg	2Cg	60-70	1	34.3	39.7	26	4
62			Peat Soil (*Terric Histosol*)					
	PO	H1	4-0	n.d.	n.d.	n.d.	n.d.	n.d.
	O1	H2	0-20	n.d.	n.d.	n.d.	n.d.	n.d.
	O2	H3	15-55	n.d.	n.d.	n.d.	n.d.	n.d.
	O3	H4	60-70	n.d.	n.d.	n.d.	n.d.	n.d.
	D	2C	80-90	0	95.8	3.2	1	0

n.d. - not determined.

Table 2. Basic chemical properties of selected soil types of the Lasy Janowskie Landscape Park (see also [5] and [17])

Soil profile No.	Genetic horizon PTG (1989)	Genetic horizon FAO-UNESCO Revised Legend (1997)	Depth (cm)	pH in 1 M KCl	Corg. (%)	Org. matter (%)	Hh cmol (+)/kg	Alw cmol (+)/kg
15*	Typic Gley Soil (*Distric Gleysol*)							
	O	O	4-0	2.9	n.d.	72.0	105.60	6.32
	A	A	1-7	2.9	2.34	n.d.	9.45	1.62
	G1	Cg1	20-30	3.8	0.18	n.d.	2.02	0.87
	G2	Cg2	50-60	4.1	0.15	n.d.	2.02	0.67
24	Podzolized Brown Acid Soil (*Cambic Podzol*)							
	O	O	4-0	3.5	n.d.	23.8	36.60	3.44
	A	A	0-4	3.5	1.54	n.d.	5.55	1.25
	AE	AE	10-20	4.1	0.28	n.d.	2.02	0.71
	B(fe,br)C	BC	28-38	4.2	0.08	n.d	1.12	0.34
	IIC	2C	45-55	3.9	0.14	n.d.	2.47	0.74
	IIIC	3C	80-90	4.2	n.d.	n.d.	0.75	0.19
25	Typic Podzol Soil (*Haplic Podzol*)							
	O	O	0-7	3.0	n.o.	72.4	82.20	1.80
	A	A	5-15	2.9	2.13	n.d.	7.35	1.11
	Ees	E	15-25	3.4	0.24	n.d.	1.35	0.45
	Box	Bsm	31-40	4.2	2.12	n.d.	10.65	2.42
	Bfe	Bs	50-60	4.6	0.30	n.d.	2.55	0.63
	C1	C1	70-80	4.7	0.09	n.d.	1.05	0.23
	C2	C2	130-140	4.5	0.07	n.d.	1.05	0.53
30	Podzolized Rusty Soil (*Cambic Arenosol*)							
	O	O	0-3	3.2	n.d.	66.9	60.40	2.45
	AEes	AE	5-15	3.1	2.25	n.d.	8.10	1.85
	Bfe	Bs	18-27	4.2	0.53	n.d.	3.15	0.86
	Bv	Bw	30-40	4.4	0.20	n.d.	1.65	0.46
	BvC	BC	50-60	4.7	n.d.	n.d.	0.90	0.23
	C	C	115-125	4.7	n.d.	n.d.	0.45	0.12
54	Typic River Alluvial Soil (*Eutric Fluvisol*)							
	A1	A1	2-10	4.4	2.02	n.d.	7.20	0.32
	A2	A2	14-20	4.5	0.78	n.d.	3.22	0.09
	C	C	25-35	4.6	0.13	n.d.	1.65	0.12
	Cgg	Cg	50-60	5.0	n.d.	n.d.	0.75	0.05
	IIC1gg	2Cg1	76-80	5.1	n.d.	n.d.	2.17	0.05
	IIC2gg	2Cg2	81-86	4.6	n.d.	n.d.	1.05	0.05
	IIC3gg	2Cg3	87-97	6.1	n.d.	n.d.	0.60	0.08
55	Degraded (Gray) Black Earth (*Gleyic Phaeozem*)							
	Ap	Ap	5-15	6.3	0.45	n.d.	1.12	0.07
	A	A	18-28	6.6	0.33	n.d.	0.97	0.04
	C	C	35-45	5.7	0.07	n.d.	0.90	0.10
	IICgg	2Cg	60-70	4.4	n.d.	n.d.	1.95	0.19
62	Peat Soil (*Terric Histosol*)							
	PO	H1	4-0	2.8	n.d.	82.9	132.60	8.60
	O1	H2	0-20	2.7	n.d.	85.2	160.80	10.00
	O2	H3	15-55	3.0	n.d.	74.6	146.40	16.70
	O3	H4	60-70	3.1	n.d.	59.4	126.00	14.60
	D	2C	80-90	3.8	0.09	n.d.	2.20	0.49

n.d. - not determined.

T a b l e 3. Sorptive properties of selected soil types of the Lasy Janowskie Landscape Park

Soil profile No.	Genetic horizon PTG (1989)	Genetic horizon FAO-UNESCO Revised Legend (1977)	Depth (cm)	Exchangeable cations cmol (+)/kg Ca^{2+}	Mg^{2+}	K^+	Na^+	S cmol (+)/kg	T cmol (+)/kg	V (%)
15	Typic Gley Soil (*Distric Gleysol*)									
	O	O	4-0	6.95	1.62	1.03	0.25	9.85	115.45	8.53
	A	A	1-7	0.61	0.16	0.11	0.05	0.893	10.38	8.96
	G1	Cg1	20-30	0.27	0.07	0.22	0.05	0.61	2.63	23.19
	G2	Cg2	50-60	0.43	0.09	0.39	0.04	0.95	2.97	31.99
24	Podzolized Brown Acid Soil (*Cambic Podzol*)									
	O	O	4-0	4.75	1.15	1.06	0.06	7.02	43.62	16.00
	A	A	0-4	0.38	0.14	0.15	0.05	0.72	6.27	11.48
	AE	AE	10-20	0.13	0.07	0.07	0.04	0.31	2.33	13.30
	B(fe,br)CII	BC	28-38	0.25	0.08	0.07	0.04	0.44	1.56	28.21
	IIC	2C	45-55	2.47	1.08	0.17	0.05	3.77	6.24	60.42
	IIIC	3C	80-90	0.70	0.24	0.07	0.04	1.05	1.80	58.33
25	Typic Podzol Soil (*Haplic Podzol*)									
	O	O	0-7	8.09	1.49	1.16	0.13	10.87	93.7	11.68
	A	A	5-15	0.28	0.06	0.06	0.03	0.43	7.78	5.53
	Ees	E	15-25	0.11	0.03	0.02	0.02	0.18	1.49	12.08
	Box	Bsm	31-40	0.15	0.03	0.03	0.02	0.23	10.88	2.11
	Bfe	Bs	50-60	0.08	0.02	0.02	0.02	0.14	2.39	5.86
	C1	C1	70-80	0.08	0.02	0.02	0.02	0.14	1.19	11.76
	C2	C2	130-140	0.09	0.02	0.04	0.02	0.17	1.22	13.93
30	Podzolized Rusty Soil (*Cambic Arenosol*)									
	O	O	0-3	8.74	1.34	1.03	0.13	11.24	71.64	15.69
	AEes	AE	5-15	0.47	0.07	0.05	0.02	0.61	8.71	7.00
	Bfe	Bs	18-27	0.11	0.03	0.02	0.02	0.18	3.33	5.41
	Bv	Bw	30-40	0.10	0.02	0.02	0.02	0.16	1.81	8.84
	BvC	BC	50-60	0.08	0.02	0.01	0.01	0.12	1.02	11.76
	C	C	115-125	0.09	0.03	0.01	0.02	0.15	0.60	25.00
54	Typic River Alluvial Soil (*Eutric Fluvisol*)									
	A1	A1	2-10	3.01	0.12	0.13	0.08	3.34	10.54	31.69
	A2	A2	14-20	2.80	0.09	0.05	0.05	2.99	6.21	48.15
	C	C	25-35	2.27	0.06	0.04	0.05	2.42	4.07	59.46
	Cgg	Cg	50-60	1.40	0.07	0.02	0.04	1.53	2.28	67.11
	IIC1gg	2Cg1	76-80	3.24	0.74	0.11	0.08	4.17	6.34	65.77
	IIC2gg	2Cg2	81-86	3.20	0.63	0.12	0.07	4.02	5.07	79.29
	IIC3gg	2Cg3	87-97	3.03	0.38	0.08	0.06	3.55	4.15	85.54
55	Degraded (Gray) Black Earth (*Gleyic Phaeozem*)									
	Ap	Ap	5-15	2.72	0.44	0.12	0.04	3.32	4.44	74.77
	A	A	18-28	2.87	0.40	0.09	0.04	3.40	4.37	77.80
	C	C	35-45	1.70	0.21	0.07	0.04	2.02	2.92	69.18
	IICgg	2Cg	60-70	3.00	0.81	0.16	0.06	4.03	5.98	67.39
62	Peat Soil (*Terric Histosol*)									
	PO	H1	4-0	4.10	1.11	0.43	0.18	5.82	138.42	4.20
	O1	H2	0-20	2.84	0.78	0.19	0.25	4.06	164.86	2.46
	O2	H3	15-55	1.40	0.35	0.13	0.10	1.98	148.38	1.33
	O3	H4	60-70	1.46	0.43	0.14	0.14	2.17	128.17	1.69
	D	2C	80-90	0.11	0.05	0.02	0.03	0.21	2.41	8.71

Table 4. Buffering surface in alkaline (P_{NaOH}) and acid (P_{HCl}) range of the selected soil types of the Lasy Janowskie Landscape Park

Soil profile No.	Genetic horizon PTG (1989)	Genetic horizon FAO-UNESCO Revised Legend (1997)	Depth (cm)	P_{NaOH} (cm^2)	P_{HCl} (cm^2)	P_{NaOH}:P_{HCl}
15	Typic Gley Soil (*Distric Gleysol*)					
	O	O	4-0	78.00	8.73	8.9
	A	A	1-7	36.50	2.42	15.1
	G1	Cg1	20-30	15.15	3.02	5.0
	G2	Cg2	50-60	10.63	3.56	3.0
24	Podzolized Brown Acid Soil (*Cambic Podzol*)					
	O	O	4-0	45.58	9.29	4.9
	A	A	0-4	26.21	4.35	6.0
	AE	AE	10-20	10.32	4.06	2.5
	B(fe,br)C	BC	28-38	15.86	6.47	2.4
	IIC	2C	45-55	7.29	3.69	2.0
	IIIC	3C	80-90	8.26	2.78	3.0
25	Typic Podzol Soil (*Haplic Podzol*)					
	O	O	0-7	55.19	6.17	8.9
	A	A	5-15	33.37	3.86	8.6
	Ees	E	15-25	14.32	3.32	4.3
	Box	Bsm	31-40	50.12	18.44	2.7
	Bfe	Bs	50-60	22.18	14.48	1.5
	C1	C1	70-80	14.22	10.46	1.3
	C2	C2	130-140	9.15	3.33	2.7
30	Podzolized Rusty Soil (*Cambic Arenosol*)					
	O	O	0-3	43.75	6.55	6.7
	AEes	AE	5-15	33.10	3.72	8.9
	Bfe	Bs	18-27	21.05	8.32	2.5
	Bv	Bw	30-40	9.22	7.73	1.2
	BvC	BC	50-60	14.13	9.64	1.5
	C	C	115-125	11.13	7.76	1.4
54	Typic River Alluvial Soil (*Eutric Fluvisol*)					
	A1	A1	2-10	30.43	20.24	1.5
	A2	A2	14-20	21.01	11.38	1.8
	C	C	25-35	9.17	7.36	1.2
	Cgg	Cg	50-60	7.25	4.67	1.5
	IIC1gg	2Cg1	76-80	14.12	15.57	0.9
	IIC2gg	2Cg2	81-86	2.50	9.35	0.3
	IIC3gg	2Cg3	87-97	6.11	10.35	0.6
55	Degraded (Gray) Black Earth (*Gleyic Phaeozem*)					
	Ap	Ap	5-15	16.10	11.74	1.4
	A	A	18-28	14.36	14.68	1.0
	C	C	35-45	11.78	4.51	2.6
	IICgg	2Cg	60-70	7.74	8.57	0.9
62	Peat Soil (*Terric Histosol*)					
	PO	H1	4-0	76.54	6.76	11.5
	O1	H2	0-20	74.75	6.32	11.8
	O2	H3	15-55	60.30	7.28	8.3
	O3	H4	60-70	68.11	8.69	7.8
	D	2C	80-90	8.23	2.33	3.5

n.d. - not determined.

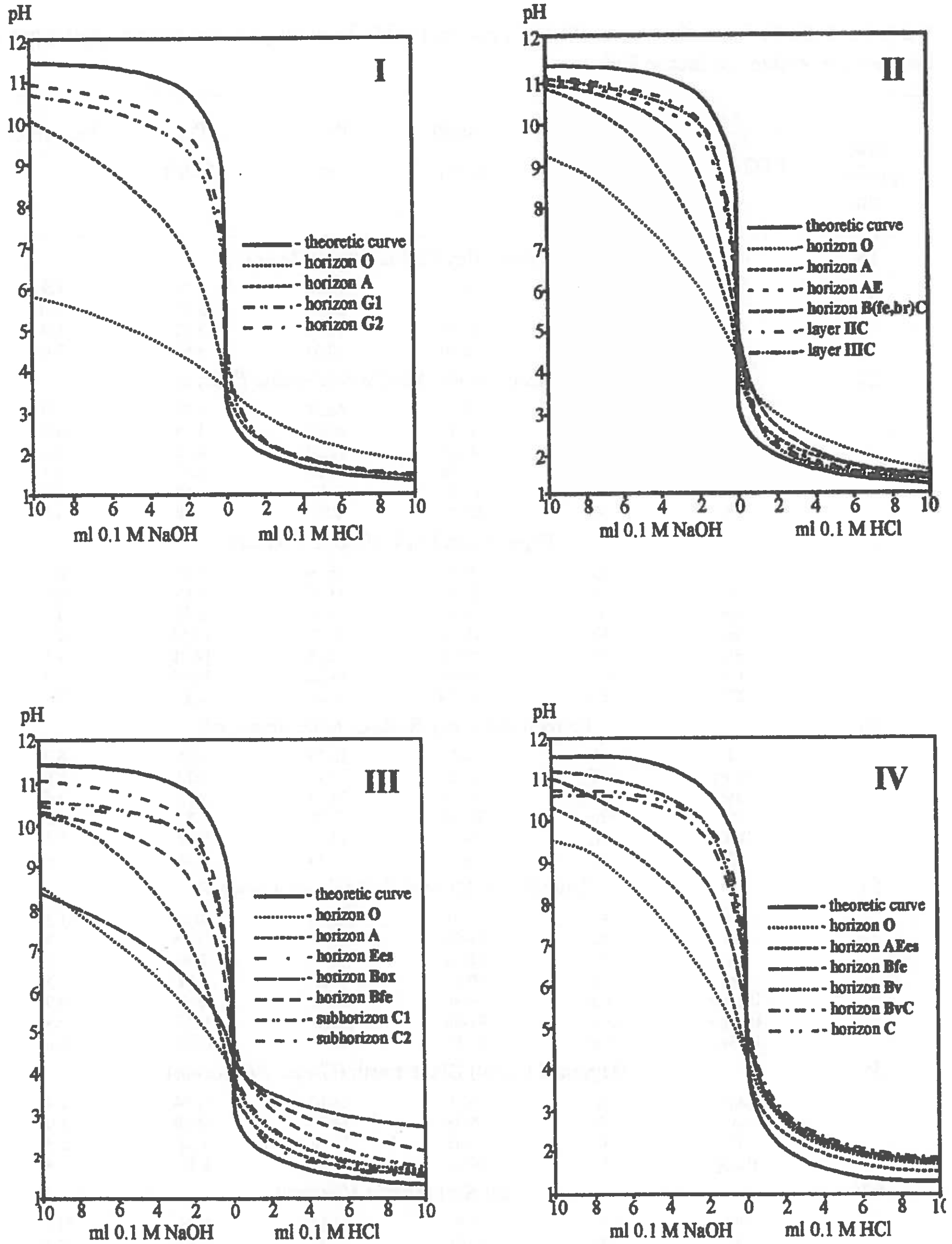

Fig. 2. Buffer curves for the studied soil types: I - Typic Gley Soil (*Dystric Gleysol*), profile 15; II - Podzolic Brown Acid Soil (*Cambic Podzol*), profile 24; III - Typic Podzol Soil (*Haplic Podzol*), profile 25; IV - Podzolized Rusty Soil (*Cambic Arenosol*), profile 30.

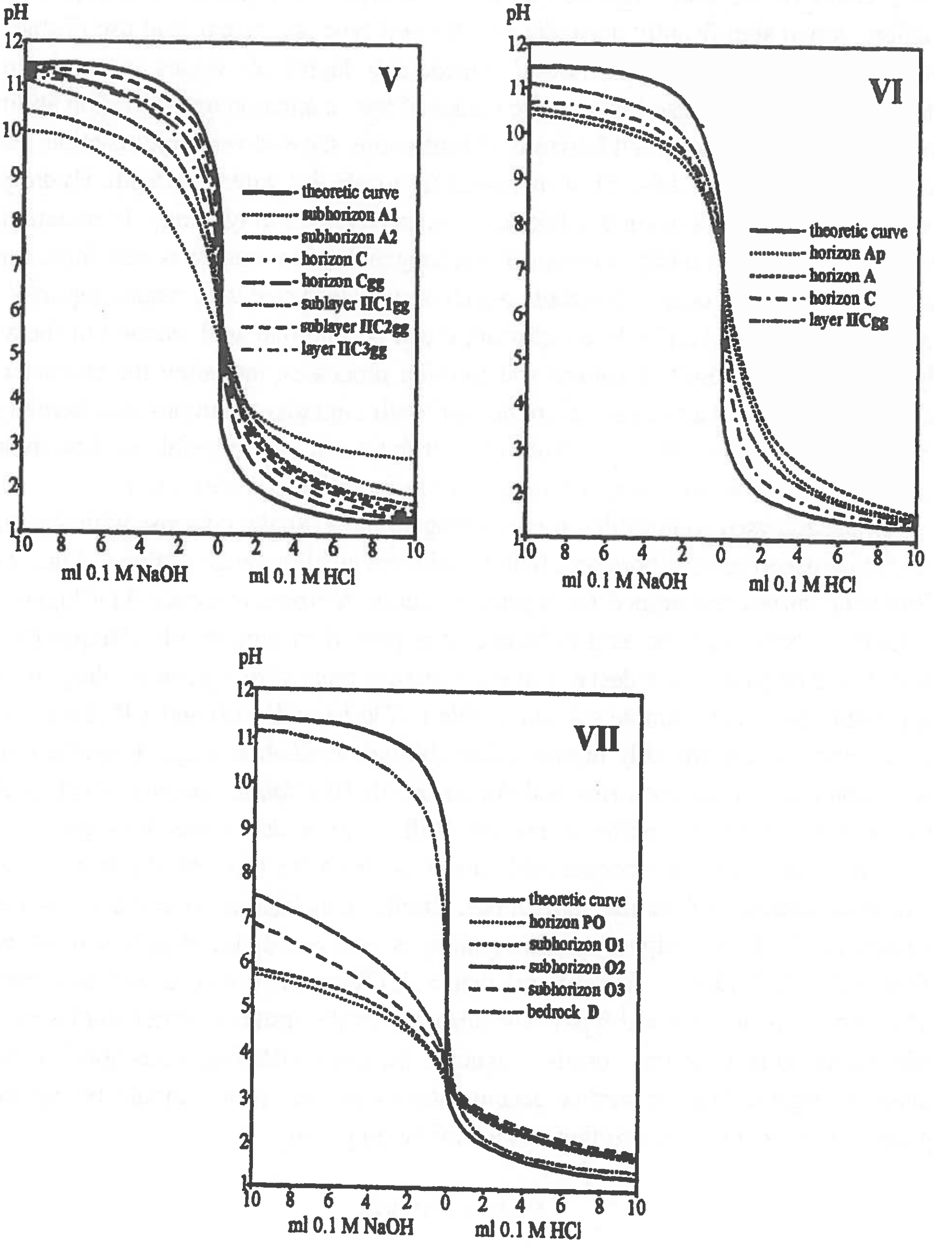

Fig. 3. Buffer curves for the studied soil types: V - Typic River Alluvial Soil (*Eutric Fluvisol*), profile 54; VI - Degraded (Gray) Black Earth (*Gleyic Phaeozem*), profile 55; VII - Peat Soil (*Terric Histosol*), profile 62.

The results of the study indicate that all the analysed soil properties, except soil reaction, varied significantly depending on the soil type and actual land use (Tables 3-4). Meadow and arable soils showed considerably higher pH values as compared to forest soils, and thus also higher were values of base saturation and buffering abilities in alkaline range. Almost all horizons of forest soils showed very acid reaction, especially horizon O (pH 2.8-3.5). It increased up to pH 4.7 with soil depth. Hydrolytic acidity was very high in surface horizons irrespective of soil typology. In mineral horizons it decreased rapidly. Content of exchangeable aluminum was also high, but it dropped sharply in deeper horizons, which is in accordance with results reported by other authors [1,11,12,17]. In conclusion, it can be said that acid reaction of the analysed soils is the result of natural soil-forming processes, including the character of mother rock and plant cover, in connection with climatic conditions and human-induced land use (low pH, high values of hydrolytic and exchangeable acidity, mobile aluminum, and low base saturation degree of the sorption complex, etc.).

In the analysed soil profiles, the buffering abilities usually decrease with the depth of distinguished genetic horizons, both in acid and alkaline range (Table 4, Figs. 2-3). Buffering curves determined for organic or humic horizons evidence their higher resistance to both base and acid influence. It is proved by smooth pH changes due to added acid or base, while deeper mineral horizons react with significant drop in their pH. Some soils, for example soils in profile I (*Dystric Gleysol*) and VII (*Terric Histosol*), showed considerably higher buffer abilities in alkaline range. Interesting data were obtained for horizons Box and Bfe of profile III (*Haplic Podzol*), which proves the existence of the iron buffer in this soil. Buffer curves determined for organic horizons also show that their considerable deviation from the theoretical curve is due to buffering capacity of humus compounds. Similar conclusions were drawn by other authors [1,11,12]. The highest buffering abilities from among the studied soils showed Typic Gley Soil *(Dystric Gleysol)* and Peat Soil *(Terric Histosol)*, as well as accumulation horizons of other soil types. This also proves the results of other studies that in labile mineral soils of low sorptive capacity, the only buffering protection is constituted by organic litter in surface accumulation horizons, which should be carefully protected in order to avoid further soil acidification [1,14].

CONCLUSIONS

1.The analyses showed that the very acid and acid reaction of the studied soils of various terrestrial ecosystems results both from natural soil-forming factors (acid mother rock and plant cover type, including low pH, high values of hydrolytic acidity, high content of mobile aluminum, low base saturation degree of the sorption complex, coniferous acid litter, etc.) and human-induced land use (forest, arable land and grassland).

2.Buffer properties are related to many of the studied soils characteristics, e.g. grain size distribution, sorptive capacity, organic matter content and base saturation degree.

3.Soil-forming processes significantly differentiate buffer properties of the soils studied, e.g. high acid buffering capacity of Box horizon of *Haplic Podzol* or subhorizon A1 of *Gleyic Phaeozem* were found.

4.From among the studied soil types, the greatest buffering abilities showed typic gley soil *(Dystric Gleysol)* and peat soil *(Terric Histosol)*, as well as accumulation horizons of other soil types, especially in alkaline range.

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