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BUFFER CAPACITY OF SOIL AS INDICATOR OF URBAN FOREST SOIL RESISTANCE TO DEGRADATION

Abstract. The aim of the study was to evaluate urban forest soil resistance to degradation caused by intensive anthropopressure by determination of buffer capacity. The study covered six soil profiles located in two forest complexes situated within the boundaries of the City of Lublin with reference to benchmark profiles. The material compiled for the study represented loessive soils and rusty sandy soils. The basic properties were determined for soil samples. Buffer capacity was determined by the Arrhenius method. The loessive soils were found to have higher buffer capacity (resistance to acidification and alkalinisation) as compared to the rusty soils. The decisive factor for buffer capacity of soils is the nature of their mineral part. Since the reference of the deliverables of the study regarding urban forest soils to benchmark profiles shows, degradation of soil is taking place within the agglomeration.

Forests account for a considerable portion of the area within the administrative boundaries of Lublin. Forests form two complexes, diverse in terms of the types of habitats and the species composition. The functions of the urban forests vary from environmental (buffering of urban pollution affecting the microclimate in the area) to social (leisure).

As a result of intensive use, soils in urban areas are exposed to great anthropopressure. It includes mechanical degradation of the surface but also more or less complex chemical processes.

Buffer properties are among the indicators which show the resistance of soil to degradation, including anthropogenic degradation [1, 6]. These are understood to denote the soil's ability to maintain a relatively stable pH value despite the action of acidifying or alkalinising agents. The soil's ability to neutralise the compounds which modify its pH value results from the presence of certain specific buffering substances the action of which is similar in terms of results but

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it is associated with the processes which are different in terms of the pH values at which they can run, the buffering capacity understood as the amount of acid or base which can be neutralised by a specific volume (or mass) of the soil and primarily the course of the chemical reaction [2].

The aim of the study was to determine the resistance of urban soils to degradation associated with intensive anthropopressure and to evaluate the usability of the buffer capacity of the soil as the indicator of the soil resistance to degradation. Additionally, molar ratio Ca:Al was calculated, as one of the predominantly used indicators describing interactions between Al^{3+} and base cations.

MATERIALS AND METHODS

Six study points were selected for carrying out the measurements in the two forest complexes in the City of Lublin. Additionally, reference points were selected outside the range of influence of the urban agglomeration.

The study points represent two types of soil. The variability stems from the physiographic diversity of Lublin which is situated on the borderline of extremely different geographic mezoregions. Soil profiles No. 1–3, situated in the "Stary Gaj" forest complex, represent loessive soils formed from loess. The corresponding benchmark profile (No. 4) was established in Czesławice near Lublin. Soil profiles No. 5–7 with rusty soils formed from sands of old fluvial terraces were established in the "Dąbrowa" forest complex. The benchmark profile of the rusty soils (No. 8) was established in the Village of Prawiedniki.

The basic properties of the soils were determined by means of methods commonly applied in soil science laboratories in Poland [7, 8]: pH in 1M KCl and water - electrometrically, organic carbon by means of the Turin's method, exchangeable cations - in NH_4Cl, exchangeable aluminium – by means of Sokolov's method, granulometric composition – by means of the aerometric method, as referred to in the classification of soil types in Poland. The buffer capacity was determined by means of the Arrhenius method by treating a soil sample with specific portions of acid (0.1 N HCl) and base (0.1 N NaOH), which was followed by determination of its pH value. The results were used to plot buffer capacity curves. The molar ratio of Ca:Al was also determined.

RESULTS AND DISCUSSION

The results obtained in the analyses have confirmed the theoretical assumptions related to the buffer capacity of the soils: they are closely dependent on specific properties of the soils, most of all on the characteristics of the sorptive complex, which in turn stems from granulation and the content of the organic matter in soil (Table 1).

TABLE 1. BASIC PROPERTIES OF SOILS ANALYSED

Profile No.	Horizon	C org. (%)	Exchangeable cations (cmol+ kg^{-1})						Base saturation (%)
			Ca	Mg	Na	K	Al	H	
1	O	s.o.	2.48	0.44	0.15	0.68	–	17.63	17.6
	A	1.38	0.43	0.12	0.09	0.19	2.23	12.30	6.3
	Et	0.22	0.19	0.06	0.05	0.09	1.67	5.25	7.0
	Bt	0.17	2.13	0.43	0.10	0.25	0.60	3.45	45.8
	C	0.16	1.13	0.38	0.14	0.22	0.15	3.45	35.1
2	O	s.o.	3.46	0.48	0.17	3.22	–	19.50	27.3
	A	1.45	1.44	0.32	0.14	0.58	1.81	18.30	11.9
	Et	0.64	0.25	0.06	0.09	0.10	1.97	6.30	7.4
	Bt	0.21	2.85	0.48	0.12	0.31	0.45	4.95	43.1
	C	0.08	1.88	0.43	0.11	0.18	0.15	2.25	53.6
3	O	s.o.	13.81	2.13	0.06	0.88	–	18.90	47.2
	A1	0.87	0.64	0.03	0.43	0.20	1.16	6.11	16.8
	Et	0.4	0.53	0.03	0.12	0.09	1.16	4.41	11.5
	Et/Bt	0.11	1.73	0.16	0.04	0.12	0.50	3.47	37.2
	Bt1	0.09	5.47	1.34	0.06	0.23	0.55	3.74	65.5
	C	0.06	5.88	1.40	0.08	0.22	0.14	2.64	74.2
4	O	s.o.	21.12	1.40	0.24	2.41	–	42.38	37.3
	A	3.18	0.43	0.05	0.10	0.26	4.49	15.38	5.2
	AEt	0.78	0.12	0.02	0.09	0.10	2.47	37.50	0.9
	Bt	0.18	3.40	0.23	0.10	0.21	1.91	5.70	40.9
	BC	0.14	3.67	0.21	0.11	0.18	0.59	3.23	56.4
	C	0.08	3.81	0.20	0.11	0.15	0.09	1.73	71.2
5	O	s.o.	2.49	0.42	0.01	0.44	–	25.50	11.7
	A	2.40	0.34	0.12	0.05	0.14	0.84	8.85	6.9
	Bv	0.38	0.03	0.02	0.06	0.03	0.68	3.30	4.0
	BvC	0.21	0.04	0.01	0.04	0.03	0.59	2.40	4.6
	C	0.08	0.03	0.01	0.08	0.02	0.45	1.95	6.8
6	O	s.o.	0.42	0.30	0.14	0.74	–	19.88	7.4
	A	1.27	0.14	0.02	0.04	0.09	0.89	5.85	4.7
	Bv	0.25	0.06	0.01	0.06	0.05	0.52	2.70	6.0
	C	0.04	0.03	0.01	0.03	0.06	0.44	1.35	8.9

TABLE 1. CONTINUATION

7	O	s.o.	7.03	1.23	0.04	0.48	-	17.17	33.8
	A	1.28	0.27	0.06	0.02	0.09	0.94	6.38	6.6
	AEs	0.61	0.10	0.02	0.02	0.06	0.98	4.37	4.3
	Bfe	0.26	0.07	0.01	0.02	0.04	0.79	2.99	4.6
	C	0.15	0.05	0.01	0.02	0.04	0.57	1.97	5.6
8	O	s.o.	1.89	0.36	0.07	0.25	-	32.63	7.3
	A	1.18	0.58	0.10	0.06	0.17	1.51	13.95	6.1
	Bv	0.36	0.11	0.02	0.10	0.08	1.25	5.10	5.8
	BvC	0.19	0.08	0.01	0.03	0.05	0.95	3.30	5.1
	C	0.06	0.01	0.06	0.04	0.18	0.61	1.65	9.2

Explanation: profiles No. 1–3 – loessive soils formed from loess, profile No. 4 – benchmark profile of loess soils, profiles No. 5–7 – rusty soils formed from sands of old fluvial terraces, profile No. 8 – benchmark profile of rusty soils.

The soils analysed within the framework of the experiment were classed as very fine sand and silt-loam (loessive soils) and slightly loamy sand and loamy sand (rusty soils) [9]. The pH values of the soils varied: the pH value in the humic layers was usually strongly acidic (only in one case it was acidic), which should be regarded as typical for forest soils as well as silty formations and loessive soils which are formed on them. The reaction (pH) of loessive soils in the bed rock was slightly acidic; that of the rusty soils was acidic.

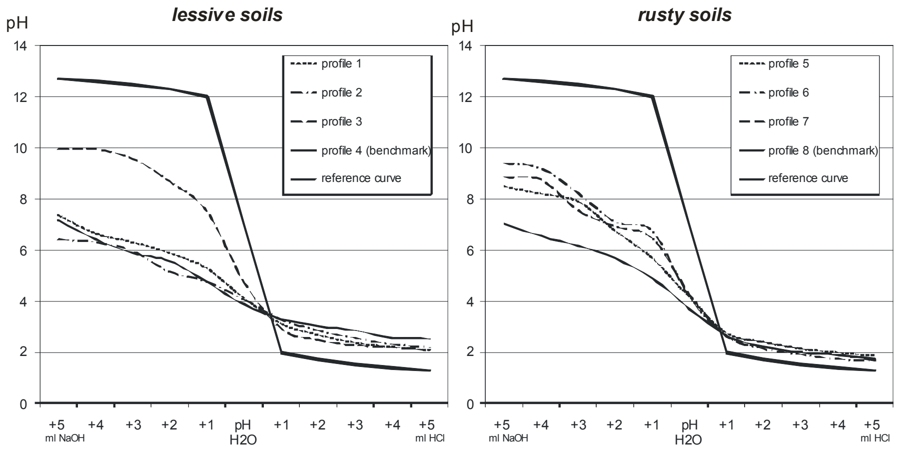

Fig. 1. Curves of buffering properties of soil investigated – humus horizon. For explanation see Table 1.

The highest buffer capacity was determined in the humus horizon of the loessive soils (Fig. 1). The reason was a relatively high content of organic matter in those layers which – combined with the texture which qualifies the formations as very fine sand and silt-loam – significantly increases the capacity for neutralisation of compounds added to the soils and changes its pH value. It should be noted that buffer capacity varies greatly – it is much higher when the soil is alkalinised than when it is acidified; in the latter case it is similar in the humus horizon and in the parent material (Fig. 2). This seems to result from a relatively low saturation of the sorptive complex with alkaline cations.

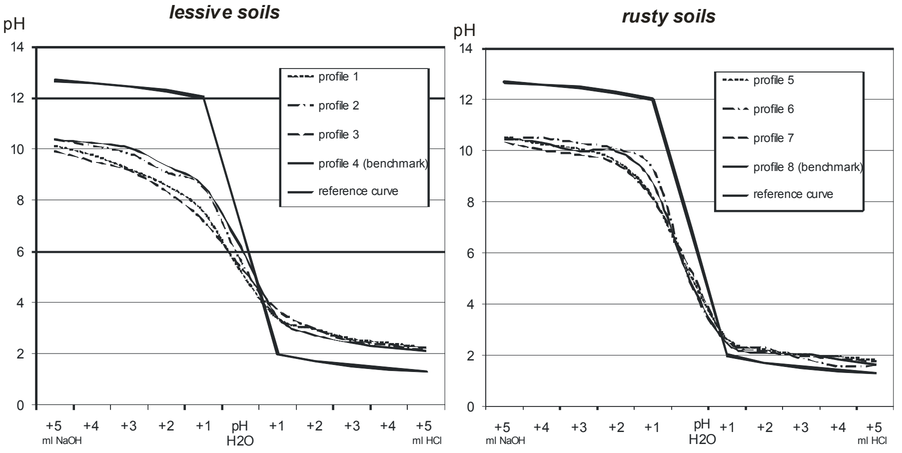

Fig. 2. Curves of buffering properties of soil investigated – parent material. For explanation see Table 1.

Despite the relatively high carbon content in the humus horizon for that type of soil, rusty soils have much lower buffer capacity. This should be associated with the low granulation of slightly loamy sand and light loamy sand which affects the size and quality of the soil sorptive complex. The buffer capacity of rusty soils is very low when they are acidified; basically, the values of the standard reference curve only slightly deviate from the values obtained for the analysed soil samples.

In the case of loessive soils, one should consider the reference to the benchmark profile which shows different buffer characteristics, namely considerably increased buffer capacity in the humic layer as compared to soils in the urban area. This reflects the anthropopressure and indicates adverse impact upon the natural environment within the city boundaries. However, as the reports of other authors prove [3, 5, 6], the soils still have considerable resistance. It can be claimed about rusty soils that intensive anthropopressure lowers their buffer capacity as compared to the benchmark profile soils. On the other hand, no variability was found in its value as far as the levels of the bed rock in both soil types are concerned. This may be a sign of considerable degradation of surface layers.

The indexes of molar ratio of Ca:Al indicate a high probability of Al stress (Table 2). The ratio is physiologically important in forest soils, while in the presence of Ca ions high concentration of Al ions is better tolerated by plant roots. It is common for description of the acid-base conditions of soil solution. Classification of Ca/Al indicator for non-organic horizons shows that below the value 0.1 of molar indicator Ca/Al aluminium stress is very likely. In the interval 0.1–1 stress is possible, and above the value 1.5 it is impossible [4]. All of the analysed loessive and rusty soils were characterized by low and very low values of molar indicator Ca/Al – below 1. It means that aluminium stress for plants is likely.

It also indicates high intensity of the lessivage and decalcification processes of A and E horizons of loessive soils. Given the lower intensity these phenomena may be found in the horizons A and E of rusty soils because parent rock in this case proves poor content of calcium carbonate. Molar ratio of Ca / Al should also be seen in relation to the changing pH of soil profiles. Generally, when pH decreases, the content of exchangeable forms of Ca decreases and the content of exchangeable Al usually increases. derived The decreasing pH contributes to the secondary effect, that is the decrease of molar ratio of Ca/Al. Especially in the rusty soils, low pH was accompanied by low and very low values of molar ratio of Ca / Al, below 0.3 in all horizons.

Particularly low values of Ca:Al were determined in the A and E levels in the loessive soils; this concerns both the profiles situated in the city and the benchmark profile. Only in the enrichment level did the index increase above 1. No significant differences between the benchmark profile and the city soils were found in the rusty soils. Yet, Al stress should be regarded as possible; moreover, due to the low calcium content, the index decreases with depth. The determination of potential stress in the surface layer of every soil brings about disadvantageous results. Nevertheless, the comparison of the soils situated within the agglomeration limits with the benchmark profiles suggests the lack of any association with the pressure of the city.

CONCLUSIONS

1. The benchmark profile in the loessive soils analysed in the study was more resistant to acidification as compared to the forest loessive soils sampled within the boundaries of Lublin. This may indicate a greater effect of anthropogenic factors (including acidification) on degradation of soils which are under pressure of the city.

TABLE 2. MOLAR RATIO Ca:Al IN SOILS ANALYSED

Profile No.	Horizon	Molar ratio Ca:Al
1	A	0.13
	Eet	0.08
	Bt	2.37
	C	5.01
2	A	0.53
	Eet	0.09
	Bt	4.22
	C	8.36
3	A1	0.37
	Eet	0.30
	Eet/Bt	2.31
	Bt1	6.63
	C	28.00
4	A	0.06
	AEet	0.03
	Bt	1.19
	BC	4.14
	C	29.91
5	A	0.27
	Bv	0.03
	BvC	0.04
	C	0.05
6	A	0.10
	Bv	0.07
	C	0.05
7	A	0.19
	AEes	0.07
	Bfe	0.06
	C	0.05
8	A	0.26
	Bv	0.06
	BvC	0.06
	C	0.06

Explanation: as in Table 1.

2. For rusty soils, differences can be found in resistance to alkalinisation between the benchmark profile and soils sampled in the forest complexes; the resistance is similar in the case of acidification.

3. A comparative analysis of the buffer properties of the soil profiles shows that the buffer capacity (resistance to acidification and to alkalinisation) is much smaller in rusty soils than in loessive soils.

4. With comparable content of organic carbon in the surface layers and in the bed rock layers of rusty and loessive soils, these are the properties of the soil-forming mineral part that account for the decisive factor as far as their buffer capacity is concerned.

5. The Ca:Al molar ratio indicates the high susceptibility of soils to Al stress; however, it was not found to result from the pressure of the agglomeration.

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BUFOROWOŚĆ GLEBY JAKO WSKAŹNIK ODPORNOŚCI NA DEGRADACJĘ MIEJSKICH GLEB LEŚNYCH

Celem pracy była ocena odporności gleb leśnych miasta na degradację związaną z intensywną antropopresją, poprzez oznaczenie ich buforowości. Badaniami objęto sześć profili glebowych zlokalizowanych w dwóch kompleksach leśnych położonych w obrębie miasta Lublina, w nawiązaniu do profili reperowych. Zgromadzony materiał reprezentował gleby płowe lessowe oraz rdzawe piaszczyste. W próbach glebowych określono podstawowe właściwości. Buforowość określono metodą Arrheniusa. Ustalono, że gleby płowe cechuje wyższa pojemność buforowa (odporność na zakwaszenie i alkalizację), w porównaniu do gleb rdzawych. Decydującym czynnikiem warunkującym zdolności buforowe gleb jest charakter mineralnej części gleby. Odniesienie badań leśnych gleb miejskich do profili reperowych sugeruje, że w obrębie aglomeracji następuje degradacja środowiska glebowego.