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Physical and chemical properties of selected soils from the surroundings of the Magura National Park (southern Poland)

Abstract: The aim of the study was to investigate the basic physicochemical and chemical properties of six soil profiles located in the surrounding of the Magura National Park (S Poland). The type of agricultural use and terrain relief were the main criteria for choosing the soil profiles. The research identified the following types or sub-types of soils: Eutric Gleysols, Dystric Cambisols, Eutric Cambisols, Gleyic Luvisols. The analyzed soils were characterized by particle size distribution of a silty clay or silt. They were usually strongly acidified as evidenced by low pH (in 1M KCl, values ranged from 3.8 to 5.8), high values of hydrolytic acidity (from 0.8 up to 10 cmol(+)·kg^{-1}) and exchangeable acidity (from 0.05 to 4.05 cmol(+)·kg^{-1}), as well as remarkable concentration of exchangeable aluminum (from 0 to 3.96 cmol(+)·kg^{-1}). The organic carbon content in studied profiles did not exceed (except from gley soil in profile) 30 g·kg^{-1} and it decreased along with the depth to several g·kg^{-1} in parent rock. These soils were characterized by not very high content of total nitrogen (from 0.3 to 9.39 g·kg^{-1}) and low available phosphorus concentration (from 3.5 to 90.3 mg P_2O_5·kg^{-1}). Contents of available potassium (from 82 to 570 mg K_2O·kg^{-1}) and magnesium (from 33 to 412 mg Mg·kg^{-1}) allow for classifying the profiles studied as soils moderately or highly abundant in K and Mg. The highest levels of biogenic elements were determined in surface horizons. Studied soils were characterized by high total sorption capacity (T) – from 7.04 to 63.4 cmol(+)·kg^{-1}. Sum of base cations (S) reached values from 3.01 to 61.2 cmol(+)·kg^{-1}, which resulted in high base saturation (V) (maximum over 96%). The base saturations in profiles of the soils increased along with depth.

Keywords: soil profile, Magura National Park, physicochemical properties of soils

INTRODUCTION

Soil plays the role of an intermediary between abiotic and biotic part of the natural environment (Niemyska-Łukaszuk et al. 2002). Recognition of soil cover, its origin, and properties of its constituent taxa, is of particular importance when assessing the natural resources of the natural environment and its protection. In the Carpathians, like in other mountain systems, development of soil cover and soil distribution refers to the geological substrate, to the intensity of geomorphological processes shaping the parent material of soils (slope cover) and to the climate and vegetation conditions (Skiba 1995).

The state of knowledge of the natural environment in Polish national or landscape parks is diverse. Some national parks, such as Babia Góra, Białowieża, Bieszczady, Karkonosze, Kampinos, Magura, Ojców, Pieniny, Roztocze, Słowiński, and especially Tatra NP, have almost complete data from numerous scientific studies, including both abiotic and biotic environment (Skiba 2007). The Low Beskids, in which Magura National Park is located, belong to middle and low mountains and is entirely included to the Western Carpathians (Kondracki 1978). The main message for the creation of the Magura National Park (MNP) was the need of the highest protection of the typical landscape of the lowest part of Polish Carpathians, i.e. Low Beskids. Location of the Park at the crossroads of major ecological corridors "north-south" and "east-west" including the transition zone between the Eastern and Western Carpathians, was equally important argument (Czaderna 2009).

Area of the MNP is located in the southern part of the Flysch Carpathians and is built mainly of sedimentary flysch rocks belonging to the outermost tectonic-facies unit – the Magura unit. Only along the north-eastern border of the Park, a small fragment of the Dukla and Silesia unit are outcropped from beneath the Magura unit. Within the Magura Nappe, in the area of Świątkowa, a fragment of Grybów unit, that presumably constitutes the south-eastern extension of the Dukla unit, emerges in a small tectonic window (Ślączka 2003). Mountain ridges in the MNP and its buffer zone are made of weathering-resistant Magura sandstone complexes.

The soil cover of the Park refers to the weathering covers of a flysch substrate. Medium depth and deep loamy brown leached and acidic soils prevail (Skiba 2009). Low Beskids soils are not widely described in

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the scientific literature. By 1995, when MNP was created, studies in Low Beskids were carried out mainly on agriculturally used areas in the region of Foothills and the Jasło-Sanok Pits (Dobrzański 1963, Komornicki et al. 1985, Zasoński 1992). Functioning of the agricultural-forest border was also studied (Adamczyk et al. 1973, Adamczyk et al. 1980), as well as porosity of the flysch parent rock of soils of Low Beskids (Maciaszek and Wójcik 1990). After creating the Magura National Park, works upon preparation of the first Protection Plan for the Park started. In view of the fact that the existing knowledge of the soil cover was inadequate, the soil map of Magura National Park began to develop in 1997. The soil and cartographic works were conducted by soil scientists from Kraków under direction of Prof. Stefan Skiba. In 2000, the soil map of MNP at 1:25 000 scale was prepared (Skiba et al. 1999). General and detailed characterization of soils in Magura National Park was published (Skiba and Drewnik 2000, Skiba et al. 2003). Because of relatively poor scientific literature on the soil environment in MNP buffer zone, the authors of the present paper attempted to determine selected physicochemical and chemical properties of soils in the immediate vicinity of the Park. Results presented in the paper are a fragment of a broader study upon the composition and basic properties of soils developed from different parent rocks of diverse direction of land use.

MATERIALS AND METHODS

The fieldworks in the surroundings of the MNP were conducted in autumn 2013. In the field, six soil profiles were made. They were located in the the following villages: Folusz (profile 1), Mrukowa (profile 2), Desznica – G. Jeleń (profile 3), Desznica (profile 4), Grab (profile 5), Bednarka – Łysa Góra (profile 6). When choosing the profile sites, the type of agricultural use and geomorphological conditions of the area were the main guidelines. The soil profiles were described as recommended by the Polish Society of Soil Science (Classification of Polish Soils 2011). Color of the soil material was determined in the wet state directly in the field using the Munsell Soil Color Charts. The soil samples were collected from separated genetic horizons, in which following items were determined: size distribution by Bouyoucos aerometric-sieve method modified by the Casagrande and Prószyński according to the norm PN 04032 (1998), organic carbon (Corg) – the Tiurin method, pH in H_2O and in 1M KCl – potentiometrically, exchangeable acidity (Hw) and exchangeable aluminum (Al^{3+}) – the Sokołow method, hydrolytic acidity (Hh) – the Kappen method, total nitrogen content (N_{tot}) – the Kjeldahl method, available phosphorus forms (P_p), available potassium forms (K_p) – the Egner-Riehm method, available magnesium forms (Mg_p) – the Schachtschabel method, exchangeable alkaline cations (Ca^{2+}, Mg^{2+}, K^+, and Na^+) – the Pallmann method, and sorption complex capacity – calculated as a sum of exchangeable bases and hydrolytic acidity (T=S+Hh) (Ostrowska et al. 1991; Ostrowska et al. 2001). Chemical analyses were performed in triplicate.

Results were subject to statistical analysis using the software Statistica 10. In order to determine the effect of soil-forming processes on the relationship between analyzed parameters, the correlation coefficients (r_{xy}) were calculated separately for the humus and parent rock horizons.

RESULTS AND DISCUSSION

Studied profiles were located in the immediate vicinity of the MNP on areas used agriculturally as meadows and pastures. According to the Classification of Polish Soils (2011), studied profiles were preliminarily ascribed to the following types or sub-types: gleby glejowe typowe (GWt) – profile 1 (Eutric Gleysols according to the WRB classification), gleby brunatne dystroficzne typowe (BDt) – profiles 2,4, (Dystric Cambisols), gleby brunatne eutroficzne wyługowane (EBwy) – profile 3,4 (Eutric Cambisols), gleby kulturoziemne regulówkowe (AKre) – profile 5 (Eutric Cambisols) and gleby płowe próchniczne (PWpr) – profile 6 (Gleyic Luvisols). Thickness of studied profiles was about 100 cm or less. These soils were mainly characterized by the texture of silty clay and silt. They had relatively bright color (Table 1). All profiles investigated were characterized by a humus horizon reaching up to about 25 cm with a clear transition, which proves that the soils studied were arable use previously.

Acidity of tested soils was diverse (Table 1). The pH value in water suspension oscillated from 4.9 in C horizon of profile 2, to 7.2 in C horizon of profile 3, while in 1M KCl it was lower and amounted from 3.4 in Bt horizon of profile 6, to 5.9 in G horizon of profile 1. The humus horizons were acidic: pH_{H2O} was from 5.0 in profiles 2, 5 to 5.4 in profiles 1, 3 and 4, whereas in 1M KCl it amounted from 4.0 in profile 2 to 4.5 in profile 1. Mean pH value (calculated based on the arithmetic mean of the hydrogen ions concentration) of BEwy soils (profile 3, 4) was clearly higher than average pH of BDt soils (profile 2). The pH values in profiles 1, 2, and 4 remained on a similar level regardless of the depth, whereas in profiles 3 and 5, they increased along with the depth. Skiba et

TABLE 1. Selected physical and physicochemical properties of soils from surroundings of Magura National Park

Profile No.	Genetic horizon	Depth [cm]	Horizon colour	Soil texture SGP5/WRB	pH		Hh	Hw	Al^{3+}
					H_2O	KCl	$cmol(+)\cdot kg^{-1}$		
Gleba glejowa typowa (GWt) – Eutric Gleysols									
1	A1	5–0	2.5Y 3/1	*pl/S	5.4	4.5	10.0	0.34	0.12
	A2	0–10	2.5Y 4/2	ps/S	5.2	4.4	9.0	0.31	0.12
	A/G	10–20	2.5Y 5/3	pg/LS	5.5	4.5	6.6	0.16	0.05
	G	20–50	2.5Y 6/2	pg/LS	6.0	5.9	2.2	0.13	0.05
	2G	50–100	10YR 6/6	pyg/SiL	5.6	4.2	2.6	0.32	0.25
	3G	<100	2.5Y 7/4	gpyi/SiCL	5.8	4.1	3.0	0.51	0.02
				Mean	5.5	4.4	5.6	0.30	0.10
Gleba brunatna dystroficzna typowa (BDt) – Dystric Cambisols									
2	A	0–15	10YR 6/1	pyg/SiL	5.0	4.0	7.0	2.13	1.96
	Bw	15–45	10YR 6/6	gp/SL	5.0	3.8	4.6	3.18	3.11
	C	45–95	7.5YR 5/6 i 10YR 8/1	pyg/SiL	4.9	4.0	4.2	2.58	2.51
				Mean	5.0	3.9	5.3	2.63	2.53
Gleba brunatna eutroficzna wyługowana (BEwy) – Eutric Cambisols									
3	A	0–5	10YR 3/2	gp/SL	5.4	4.4	4.5	0.32	0.19
	A/B	5–25	10YR 4/2	gp/SL	6.3	4.8	3.4	0.10	0.02
	Bw	25–50	10YR 4/4	gp/SL	6.5	5.2	0.8	0.05	0.00
	C	5–100	10YR 4/6	pyg/SiL	7.2	5.6	0.8	0.07	0.00
4	A1	0–4	7.5YR 4/1	gp/SL	5.4	4.2	6.8	0.79	0.60
	A2	4–20	7.5 YR 3/1	gp/SL	5.3	4.1	6.0	1.38	1.26
	Bw	20–50	10YR 6/4	gp/SL	5.4	3.9	3.8	1.82	1.79
	C	<50	10YR 6/6	pyg/SiL	5.3	4.0	2.8	1.53	1.44
				Mean	5.5	4.3	3.6	0.76	0.70
Gleba antropogeniczna kulturoziemna regulówkowa (AKre) – Eutric Cambisols (Aric)									
5	A	0–25	10YR 6/3	pyg/SiL	5.0	4.1	6.2	1.01	0.87
	A2	25–75	10YR 5/4	pyg/SiL	5.1	4.0	6.6	1.75	1.62
	2BW	75–105	10YR 5/1	gz/L	5.6	4.5	6.2	0.66	0.51
	3C	<105	10YR 6/3	gp/SL	5.5	4.4	5.8	0.54	0.31
				Mean	5.3	4.2	6.2	0.99	0.83
Gleba płowa próchniczna (PWpr) – Gleyic Luvisols									
6	A1	0–5	10 YR 5/3	gp/SL	5.2	4.2	5.8	0.59	0.43
	A2	5–25	10YR 6/3	gp/SL	5.3	4.3	3.0	0.60	0.48
	Et	25–45	10YR 7/4	pyg/SiL	5.0	3.9	5.8	3.01	2.90
	Bt	45–70	10YR 6/6	pyi/SiL	5.3	3.4	7.0	4.05	3.96
	Cg	<70	5 Y 6/1 i 10 YR 5/8	gpyi/SiCl	5.9	4.8	1.8	0.07	0.00
				Mean	5.4	4.1	4.7	1.7	1.6

*pl/S – piasek luźny/Sand, ps/S – piasek słabogliniasty/Sand, pg/LS – piasek, gliniasty/loamy sand, gp/SL – glina piaszczysta/sandy loam, gz/L – glina zwykła/loam, gpyi/SiCL – glina pylasto-ilasta/silty clay loam, pyi/SiL – pył ilasty/silt loam, pyg/SiL – pył gliniasty/silt loam.

al. (2003) reported similar results when studying soils of The Magura National Park. Results achieved by Skiba and Drewnik (2000) indicate that values and distribution of pH within soil profiles of the Park can be associated with the mantle rock of the Carpathian Flysch, and on the other hand with the influence of migrating subsurface waters. The study of soils from MNP buffer zone confirms these observations.

Acidity of analyzed soils was high: hydrolytic acidity ranged from 0.8 $cmol(+)\cdot kg^{-1}$ in Bw and C horizons of profile 3, to 10 $cmol(+)\cdot kg^{-1}$ in A1 horizon of profile 1, whereas exchangeable acidity was lower: from 0.05 $cmol(+)\cdot kg^{-1}$ in Bw horizon of profile 3 to 4.05 $cmol(+)\cdot kg^{-1}$ in Bt horizon of profile 6. In most of the studied soils, acidity was the highest in humus horizons and it decreased with depth. The highest exchangeable acidity was typical of BDt soil (2.63 $cmol(+)\cdot kg^{-1}$, on average), whereas the lowest – GWt soil (0.30 $cmol(+)\cdot kg^{-1}$, on average). This resulted in a considerable content of exchangeable aluminum; maximum 3.96 $cmol(+)\cdot kg^{-1}$ in Bt horizon of profile 6. Quantity of Al^{3+} at humus horizons and the parent rock of analyzed soils was strongly associated with their exchangeable acidity, which was indicated by correlation coefficients (Table 4, 5). The highest concentrations of exchangeable aluminum were reported for BDt soil. Interestingly, among studied genetic horizons, the highest amounts of aluminum were found in cambic, luvic and argic horizon of these soils – profiles 2, 4, 6. In other soil profiles, the humus horizons were characterized by the highest levels of exchangeable acidity and mobilized aluminum. Remarkable amounts of exchangeable aluminum (0.23–7.62 cmol(+)·kg^{-1}) in soils of 3 profiles of different Polish soil types were also reported by Porębska et al. (2008), who noted a tendency to decrease the exchangeable Al with depth. In addition, Al^{3+} ion was the prevalent acidic ion at mineral horizons of these soils.

The organic carbon content in studied soils was in general not so high. It amounted at accumulation horizons from 11 g·kg^{-1} in A2 horizon of profile 6, up to 102 g·kg^{-1} in A1 horizon of profile 1 (Table 2). At deeper horizons, it was even lower ranging from 1 g·kg^{-1} in horizon C of profile 2, to 19 g·kg^{-1} in G horizon of profile 1. However, these amounts were higher than those reported by Gałka and Dębicki (2014) referring to fertile, yet strongly reliefed and exposed to erosion processes, loess soils of Sandomierz Upland. The increase in organic carbon content was found in 3C horizon of profile 5 (below 105 cm). The reason of higher organic matter amount at deeper horizon in relation to more shallow one of that profile, can be the cover with mineral formation of layers more abundant in organic matter due to anth-

TABLE 2. Selected chemical properties of soil from the surroundings of Magura National Park

Profile No.	Genetic horizon	Soil texture	Corg	N_{tot}	C/N	Available forms		
						P_2O_5	K_2O	Mg
			g·kg^{-1}			mg·kg^{-1}		
Gleba glejowa typowa (GWt) – Eutric Gleysols								
1	A1	pl	102	9.39	11	90.3	570	412
	A2	ps	50	6.70	8	36.2	201	344
	A/G	pg	34	3.62	9	15.7	151	366
	G	pg	19	0.78	25	4.6	174	372
	2G	pyg	4	0.30	15	5.5	145	214
	3G	gpyi	7	0.32	23	10.1	149	192
		Mean	36	3.52	15	27.1	232	316
Gleba brunatna dystroficzna typowa (BDt) – Dystric Cambisols								
2	A	pyg	20	1.85	11	35.3	455	33
	Bw	gp	2	0.30	8	5.1	92	58
	C	pyg	1	0.31	3	4.5	86	56
		Mean	8	0.82	7	15.0	211	49
Gleba brunatna eutroficzna wyługowana (BEwy) – Eutric Cambisols								
3	A	gp	21	2.42	9	45.9	272	168
	A/B	gp	14	1.87	8	26.7	144	177
	Bw	gp	5	0.62	8	5.1	143	187
	C	pyg	2	0.64	4	26.4	135	192
4	A1	gp	26	3.84	7	40.1	183	85
	A2	gp	18	2.21	8	17.0	82	37
	Bw	gp	5	0.59	8	18.9	82	69
	C	pyg	6	0.34	18	3.5	111	106
		Mean	12	1.57	8.8	23.0	144	128
Gleba antropogeniczna kulturoziemna regulówkowa (AKre) – Eutric ambisols (Aric)								
5	A	pyg	22	2.36	9	23.7	169	133
	A2	pyg	19	1.98	9	21.0	109	102
	2Bw	gz	8	2.69	3	54.6	196	79
	3C	gp	18	2.85	6	53.0	231	61
		Mean	17	2.47	7	38.1	176	94
Gleba płowa próchniczna (PWpr) – Gleyic Luvisols								
6	A1	gp	26	2.31	11	58.1	333	98
	A2	gp	11	1.51	7	19.9	130	65
	Et	pyg	5	0.63	7	5.0	99	52
	Bt	pyi	4	0.49	7	8.1	167	196
	Cg	gpyi	5	0.41	12	6.3	170	244
		Mean	10	1.07	9	19.5	180	131

ropogenic activity. Cutting off the air supply caused that these layers while being under the strong impact of ground water, retained a higher organic carbon content. In other profiles, typical distribution of organic carbon was observed – the highest values were found in the topsoil and Corg quantities decreased along with the depth. Similar dependence was also recorded by Du et al. (2014), when analyzing the soil properties of Lushan Mountains in China, but they observed the increase in the share of carbon in carbonyl groups and decrease in the proportion of carbon in alkyl groups with depth. Du et al. (2014) underlined the presence of a positive dependence between Corg content in soils and mean annual rainfall, while negative inter-relation with mean annual temperature (both features are closely associated with the altitude). The characteristic trait of studied Magura soils consisted in a strong dependence between Corg concentration at humus horizons vs. these soils abundance in nitrogen, available forms of potassium, magnesium, and phosphorus, as well as amount of exchangeable alkaline cations (Table 4). Organic substance at humus horizons is well humified as evidenced by C:N ratio ranging from 7 to 11. This was confirmed by results by Skiba et al. (2003). Usually at deeper horizons, the C:N ratio was slightly lower as compared to accumulation horizons. Only in the case of GWt soil, considerably higher values of the parameter at gley horizons (15–25 cm), were recorded.

Total nitrogen content in a soil depends on the amount of organic substance entering the soil, abundance of nitrogen, and the decomposition direction. The nitrogen content is assumed to be a constant feature of soil associated with its type and the method of use (Ostrowska et al. 2001). In analyzed soils (except from the anthropogenic one), content of the total nitrogen at humus horizons oscillated from 1.51 $g\cdot kg^{-1}$ in A2 horizon of profile 6, to 9.39 $g\cdot kg^{-1}$ in A1 horizon of profile 1 (Table 2). It was clear that the nitrogen content in profiles decreased with depth, as similarly as carbon content. Only in the AKre soil, the total nitrogen content increased with depth and ranged from 2.36 $g\cdot kg^{-1}$ in A horizon to 2.85 $g\cdot kg^{-1}$ in 3C horizon. Similarly, the contents of available phosphorus and potassium were higher in bottom in relation to the upper part of the profile, with maximum values in 2Bw and 3C horizons. Such a distribution of available forms of nitrogen and phosphorus, as well as potassium was most likely the result of anthropogenic activities consisting in covering the initial humus horizon with mineral formations poor both in humus, and available forms of these elements.

Analyzed soils contained the available phosphorus at the levels from 3.5 mg $P_2O_5\cdot kg^{-1}$ in C horizon of profile 4, up to 90.3 mg $P_2O_5\cdot kg^{-1}$ in A1 horizon of profile 1 (Table 2). Studied profiles were characterized by a very low or relatively low content of this component. Skiba and Winnicki (1995) reported similar results, when studying the soils of vegetation communities in Bieszczady Mountains meadows, as well as Zaleski et al. (2007), who analyzed chemical properties of soils under farrowed meadows in Wołosate village (the Bieszczady Mts.). The highest contents were determined in the topsoil, which is associated with the accumulation of organic matter. The increase in phosphorus concentration in the bottom part of the profile in GWt soil (profile 1) and BEwy soil (profile 3) was most probably associated with this component content in the parent rock.

Content of available potassium in the soils studied was diverse oscillating from 82 mg $K_2O\cdot kg^{-1}$ in A2 and Bw horizons of profile 4, to 570 mg $K_2O\cdot kg^{-1}$ in A1 horizon of profile 1 (Table 2). The highest average concentration of available potassium was found in GWt soil which amounted to 232 mg $K_2O\cdot kg^{-1}$. Brown and luvisols soils were characterized by moderate or low contents of available potassium, except for humus horizons, in which very high or high amounts of K were found. Skiba and Drewnik (2000) reported similar results when studying the soil cover of Magura National Park. Studied soils were characterized by high or very high levels of available magnesium from 33 $mg\cdot kg^{-1}$ in A horizon of profile 2 to 412 $mg\cdot kg^{-1}$ in A1 horizon of profile 1 (Table 2). Usually, amount of this Mg form increased along with the depth. The high content of the analyzed element is conditioned by chemical composition of parent rock and soil texture. The exchangeable cations sorption mechanism is the main factor responsible for the retention and release of magnesium in the soil, and sorption capacity of the soil depends on its grain size composition. The exception was the A1 horizon of profile 1 containing up to 412 mg $Mg\cdot kg^{-1}$ DM. It can be either of anthropogenic origin, introduced in the form of fertilization, or come up with groundwater abundant in magnesium, periodically stagnant on the surface, which is confirmed by gleyic color already occurring at a depth of several centimeters, and being more and more intense with depth. The higher contents of magnesium at lower horizons of profiles 4 and 6 are most likely due to a higher content of this element in the parent rock. In the case of BDt soil (profile 2), magnesium content reached its lowest level at the topsoil with the increase with depth. It could result from its leaching from upper genetic horizons, which was confirmed by relatively low field sorption capacity of 8.1 $cmol(+)\cdot kg^{-1}$, on average (Table 3).

TABLE 3. Selected physicochemical properties of soils from the surroundings of MPN

Profile No.	Genetic horizon	Soil texture	Contents of cations				S	T	V
			Ca^{2+}	Mg^{2+}	K^+	Na^+			
			cmol(+)·kg^{-1}				cmol(+)·kg^{-1}		%
Gleba glejowa typowa (GWt) – Eutric Gleysols									
1	A1	pl	33.6	10.7	0.94	1.09	46.3	56.3	82
	A2	ps	27.9	8.2	0.39	0.94	37.5	46.5	81
	A/G	pg	30.8	10.2	0.34	0.95	42.4	49.0	87
	G	pg	48.6	11.3	0.46	0.82	61.2	63.4	97
	2G	pyg	18.1	3.9	0.27	0.72	23.4	26.0	90
	3G	gpyi	17.9	3.3	0.28	0.76	22.2	25.2	88
		Mean	29.5	7.9	0.45	0.88	38.8	44.4	87
Gleba brunatna dystroficzna typowa (BDt) – Dystric Cambisols									
2	A	pyg	0.7	0.53	0.83	0.66	2.7	9.7	28
	Bw	gp	1.5	0.75	0.15	0.63	3.0	7.6	40
	C	pyg	1.6	0.79	0.13	0.55	3.0	7.0	43
		Mean	1.2	0.70	0.37	0.61	2.9	8.1	37
Gleba brunatna eutroficzna wyługowana (BEwy) – Eutric Cambisols									
3	A	gp	13.6	2.54	0.49	0.45	17.1	21.6	79
	A/B	gp	16.0	2.81	0.24	0.43	19.5	22.9	85
	Bw	gp	17.6	3.24	0.25	0.35	21.4	22.2	96
	C	pyg	17.8	3.29	0.22	0.90	22.2	23.0	97
4	A1	gp	5.8	1.15	0.29	0.80	8.0	14.8	54
	A2	gp	3.3	0.57	0.12	0.61	4.6	10.6	43
	Bw	gp	3.9	1.03	0.12	0.79	5.9	9.7	61
	C	pyg	5.4	1.49	0.17	0.78	7.9	10.7	74
		Mean	10.4	2.00	0.24	0.64	13.3	16.9	74
Gleba antropogeniczna kulturoziemna regulówkowa (AKre) – Eutric Cambisols (Aric)									
5	A	pyg	7.2	1.67	0.22	0.54	9.6	15.8	61
	A2	pyg	5.2	1.28	0.15	0.85	7.4	14.0	53
	2Bw	gz	6.2	0.93	0.26	0.57	8.0	14.2	56
	3C	gp	5.0	0.74	0.32	0.51	6.5	12.3	53
		Mean	5.9	1.16	0.24	0.62	7.9	14.1	56
Gleba płowa próchniczna (PWpr) – Gleyic Luvisols									
6	A1	gp	7.5	1.13	0.43	0.74	9.8	15.6	63
	A2	gp	7.0	0.78	0.14	0.49	8.4	11.4	74
	Et	pyg	2.8	0.56	0.10	0.46	3.9	9.7	40
	Bt	pyi	12.7	2.31	0.19	0.24	15.4	22.4	69
	Cg	gpyi	21.7	3.23	0.19	0.20	25.3	27.1	93
		Mean	10.3	1.60	0.21	0.43	12.6	17.3	68

Level of abundance of the soils studied in determined available forms of N, P, K, and Mg was mainly due to their abundance in humus, the grain size composition, and nature of the bedrock. For the most part, it was confirmed by the analysis of simple correlation coefficient between analyzed parameters (Table 4).

According to Porębska et al. (2008), a decreasing sequence of the alkaline cations amounts in soils developed from sands in three Polish regions, is as follows: Ca2+>Mg2+>K+>Na+. Calcium dominated in the occupation of the cation exchange capacity of studied soils. Its contents ranged from 0.7 cmol(+)·kg^{-1} in A horizon of profile 2 to 48.6 cmol(+)·kg^{-1} in G horizon of profile 1 (Table 3). The only exception was BDt soil (profile 2), in which in A horizon, the highest content was recorded in the case of potassium – 0.83 cmol(+)·kg^{-1} DM. Exchangeable magnesium concentration was determined at slightly lower level: from 0.5 cmol(+)·kg^{-1} in A horizon of profile 2 to 11.3 cmol(+)·kg^{-1} in G horizon of profile 1. Quantitatively significant alkaline cation being a part of cation exchange capacity of test soils was sodium, the content of which ranged from 0.20 cmol(+)·kg^{-1} (in Cg horizon of profile 6) to 1.09 cmol(+)·kg^{-1} (in A1 horizon of profile 1) exceeding potassium concentration at all horizons of analyzed soil profiles. Proportion of exchangeable potassium in the cation exchange capacity of studied soils was the lowest – its content

TABLE 4. Simple correlation coefficients between analyzed parameters at humus horizon (n=12)

Parameter	pH_{KCl}	Hh	Hw	Al^{3+}	Corg	N_{tot}	P_p	K_p	Mg_p	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	S	T
Hh	n.i.														
Hw	-0.85***	n.i.													
Al^{3+}	-0.84***	n.i.	0.998***												
Corg	n.i.	0.803**	n.i.	n.i.											
N_{tot}	n.i.	0.821***	n.i.	n.i.	0.964***										
P_p	n.i.	n.i.	n.i.	n.i.	0.787**	0.701*									
K_p	n.i.	n.i.	n.i.	n.i.	0.680*	n.i.	0.858***								
Mg_p	0.646*	n.i.	-0.651*	-0.671*	0.782**	0.810***	n.i.	n.i.							
C^{a2+}	0.722**	n.i.	-0.716**	-0.733**	0.751**	0.783**	n.i.	n.i.	0.990***						
Mg^{2+}	0.594*	0.612*	-0.576*	-0.597*	0.792**	0.812***	n.i.	n.i.	0.983***	0.978***					
K^{+}	n.i.	n.i.	n.i.	n.i.	0.682*	n.i.	0.777**	0.971***	n.i.	n.i.	n.i.				
Na^{+}	n.i.	0.869***	n.i.	n.i.	0.756**	0.771**	n.i.	n.i.	0.657*	0.605*	0.718**	n.i.			
S	0.685*	n.i.	-0.673*	-0.692*	0.774**	0.802**	n.i.	n.i.	0.993***	0.998***	0.989***	n.i.	0.647*		
T	0.626*	0.619*	-0.614*	-0.638*	0.817***	0.845***	n.i.	n.i.	0.992***	0.987***	0.994***	n.i.	0.707**	0.995***	
V	0.833***	n.i.	-0.94***	-0.93***	n.i.	n.i.	n.i.	n.i.	0.750**	0.798**	0.669*	n.i.	n.i.	0.758**	0.697*

* significant at α =0.05, ** significant at α =0.01, *** significant at α=0.001, n.i. – insignificant correlation.

TABLE 5. Simple correlation coefficients between analyzed parameters at parent rock horizon (n = 8)

Parameter	pH_{KCl}	Hh	Hw	Al^{3+}	Corg	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	S	T
Hh	n.i.										
Hw	n.i.	n.i.									
Al^{3+}	n.i.	n.i.	0.987***								
Corg	n.i.	n.i.	n.i.	n.i.							
Ca^{2+}	n.i.	n.i.	-0.817*	-0.809*	n.i.						
Mg^{2+}	n.i.	-0.821*	n.i.	n.i.	n.i.	0.966***					
K^{+}	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.				
Na^{+}	n.i.	n.i.	n.i.	n.i.	0.827*	n.i.	n.i.	n.i.			
S	n.i.	n.i.	-0.810*	-0.804*	n.i.	0.998***	0.978***	n.i.	n.i.		
T	n.i.	n.i.	-0.843*	-0.850*	n.i.	0.992***	0.950***	n.i.	n.i.	0.991***	
V	n.i.	-0.859*	n.i.	n.i.	n.i.	0.923***	0.951***	n.i.	n.i.	0.936***	0.8962**

* significant at α=0.05, ** significant at α=0.01, *** significant at α=0.001, n.i. – insignificant correlation.

was from 0.10 cmol(+)·kg^{-1} in Et horizon of profile 6 to 0.94 cmol(+)·kg^{-1} DM in A1 horizon of profile 1. Particularly great abundance in alkaline cations was recorded in topsoil (up to 50 cm deep) of gley soil in profile 1 – in total from 37.5 to 61.2 cmol(+)·kg^{-1} DM. The sum of alkaline cations in other soils did not exceed 25.3 cmol(+)·kg^{-1} DM, but the following soils were extremely poor in these elements: AKre (profile 5), BEwy (profile 4) and BDt (profile 2), in which contents of alkaline cations were 2.7–9.6 cmol(+)·kg^{-1} DM. Base saturation in majority exceeded 50%, and in GWt and BEwy soils (profiles 1 and 3), up to 80% (Table 3). Skiba et al. (2003) achieved similar results when characterizing the authogenic soils present within MNP. The opposite relationship was emphasized by Kooijman et al. (2000) in soils of the Karkonosze Mountains at much lower degree of base saturations. Generalizing, it can be concluded that saturation with alkaline cations increased with a depth of the soil profile. Higher base saturation (more than 50%) in the lower parts of profiles can be an effect of the release of chemical elements in the process of parent rock or minerals weathering, or the result of accumulation of fertile groundwater supplying these parts of the profile. A similar view was presented by Kabała et al. (2011) when studying the transformation of agriculturally used cambisols in the Silesian Lowland.

CONCLUSIONS

1. The analyzed soils were characterized by particle size distribution of a silty clay or silt formations.
2. Soils of the studied area were usually characterized by a strong acidification as evidenced by low pH and high values of hydrolytic and exchangeable acidity, as well as remarkable content of mobilized aluminum.
3. Content of organic carbon in test profiles was diverse (1–102 g·kg^{-1}) and decreased with the depth.
4. In general, soils of the studied area were characterized by low concentrations of the total nitrogen and available phosphorus, and most often high content of available potassium and magnesium.
5. In soils from individual profiles, the highest contents of analyzed biogenic elements (N, P, K) were recorded at topsoil.
6. Calcium dominated in the cation exchange capacity, followed by magnesium, sodium, and potassium. Base saturation was high in AKre soil from Folusz village and BEwy soil from Desznica village (more than 80%), while in the profile of BDt soil from Mrukowa village, it did not reach 45%.

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Właściwości fizykochemiczne i chemiczne wybranych gleb z otoczenia Magurskiego Parku Narodowego

Streszczenie: Celem pracy było określenie podstawowych właściwości fizykochemicznych i chemicznych sześciu profili glebowych zlokalizowanych w otoczeniu Magurskiego Parku Narodowego. Przy wyborze miejsc odkrywek kierowano się rodzajem użytkowania rolniczego oraz rzeźbą terenu. W wyniku badań zgodnie z SGP5 zidentyfikowano następujące typy lub podtypy gleb: glejowa typowa GWt (Eutric Gleysols), brunatna dystroficzna typowa BDt (Dystric Cambisols), brunatna eutroficzna wyługowana BEwy (Eutric Cambisols), gleba antropogeniczna, kulturoziemna regulówkowa AKre (Eutric Cambisols Aric) oraz gleba płowa próchniczna PWpr (Gleyic Luvisols). Analizowane gleby charakteryzowały się uziarnieniem glin pylastych lub utworów pyłowych. Były zazwyczaj silnie zakwaszone, o czym świadczyło niskie pH (w 1M KCl wartości zawierały się w przedziale od 3,8 do 5,8), wysokie wartości kwasowości hydrolitycznej (od 0,8 do 10,0 cmol(+)$\cdot$kg^{-1}) i wymiennej (od 0,05 do 4,05 cmol(+)$\cdot$kg^{-1}) oraz znacząca zawartość glinu wymiennego (od 0 do 3,96 cmol(+)$\cdot$kg^{-1}). Zawartość węgla organicznego w badanych profilach nie przekraczała (za wyjątkiem profilu 1) 30 g$\cdot$kg^{-1} i wraz z głębokością malała do kilku g$\cdot$kg^{-1} w poziomach skały macierzystej. Gleby te cechowały się niezbyt wysoką zawartością azotu całkowitego (od 0,30 do 9,39 g$\cdot$kg^{-1}) oraz niską zawartością fosforu przyswajalnego (od 3,5 do 90,3 mg $P_2O_5\cdot$kg^{-1}). Natomiast zawartość przyswajalnego potasu (od 82 do 570 mg $K_2O\cdot$kg^{-1}) oraz magnezu (od 33 do 412 mg Mg$\cdot$kg^{-1}) pozwalała zakwalifikować badane gleby do kategorii średnio bądź wysoko zasobnych. Najwyższe wartości pierwiastków biogennych wykrywano w poziomach powierzchniowych. Badane gleby charakteryzowały się wysoką, całkowitą pojemnością sorpcyjną (T) – od 7,0 do 63,4 cmol(+)$\cdot$kg^{-1}. Suma kationów o charakterze zasadowym (S) przyjmowała wartości od 3,0 do 61,2 cmol(+)$\cdot$kg^{-1}, co skutkowało wysokim wysyceniem kompleksu sorpcyjnego zasadami (V) (maksymalnie ponad 96%). Wysycenie kompleksu sorpcyjnego gleby kationami zasadowymi w profilach gleb wzrastało wraz z głębokością.

Słowa kluczowe: profil glebowy, Magurski Park Narodowy, właściwości fizykochemiczne gleb