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THE CONTENT OF PHOSPHORUS IN MOUNTAIN MEADOW (POLONINA) SOILS AS AN INDICATOR OF PAST SHEPHERDING ACTIVITY

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Abstract

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This research was conducted in the area of the Carynska Polonina (the Western Bieszczady, the Eastern Carpathians, Poland). The content of total phosphorus (P_2O_5_t), inorganic phosphorus (P_2O_5_in), organic phosphorus (P_2O_5_org) and phosphorus extracted with 1% citric acid (P_2O_5_ac) was determined in 8 profiles of mountain meadow (polonina) soils. The content of the examined forms of phosphorus is highest in the surface humus horizons A, but, as a rule this decreases with depth. In general, the amount of organic phosphorus (P_2O_5_org) was found to be higher than the amount of inorganic phosphorus (P_2O_5_in). The high content of phosphorus extracted with 1% citric acid (P_2O_5_ac) in soils under the *Rumicetum alpini* community may indicate the sites of past shepherding activity (shepherds' shelters and cattle accommodation) in this area. P_2O_5_ac was found to be the most useful indicator of anthropopression compared to other forms of phosphorus. The impact of human activity on the natural environment of Carynska Polonina intensified several times, and the last phase of anthropopression was connected with an increase in population and economic development in this area during the first half of the 20th century, between 1911 and 1939.

Key words: soil phosphorus, mountain meadow soils, Bieszczady National Park, past human activity

Introduction

The Western Bieszczady poloninas in the Eastern Carpathians constitute a specific plant layer developed beyond the upper tree-line with highest peaks exceeding 1200 m a.s.l. They include grass, herb and shrub communities, peatlands and high mountain swards (Winnicki, 1999). The agricultural exploitation of the Bieszczady poloninas began with the arrival of the Vlach shepherd population who drove their flocks along the entire Carpathian range from the 14th century (Marcinek, 2001). The following agricultural activities took place in the poloninas: pasturing, accommodating cattle and sheep and cutting and burning-off natural brushwood to extend the pastures. Shepherding activities had a significant impact on the range, composition and structure of the polonina plant communities (Augustyn, 2000; Winnicki, 1999).

Shepherd exploitation of the poloninas ceased in approximately 1940. Despite a lapse of a few dozen years since agricultural activity ceased, one can still find traces of past human activity on the Bieszczady poloninas. Areas of past anthropopression were located based on occurrence of some plant communities of a ruderal and nitrophilous nature. An example of such a community is *Rumicetum alpini* which is found close to shelters, tourist hostels and cattle accommodation areas (Swederski, Wilczyński, 1927; Matuszkiewicz, 2008). A similar regularity in the Alps was established by H. Ellenberg (Jewell et al., 2007). According to Winnicki (1999), some planes of herbs of *Rumex alpinus* L., occurring in the subalpine zone may have a natural character. Other traces of former human farming are to be found on the post-agricultural terraces which are still currently preserved on some Bieszczady slopes (Wolski, 2008).

One of the best indicators of human activity is the content of phosphorus in soils (Griffith 1980, 1981; Brzeziński et al., 1983; Kondratiuk, Banaszuk, 1993; Scudder et al., 1996; Simpson, 1997; Leonardi et al., 1999; Schlezinger, Howes, 2000; Parnell et al., 2002; Sullivan, Kealhofer, 2004; Marwick, 2005; Holliday, Gartner, 2007; IUSS Working Group WRB, 2006/2007; Bednarek, 2008).

The use of phosphorus as an indicator of anthropopression is connected with its poor solubility in conditions of both acidic and alkaline soil reactions. In acidic soils, $H_2PO_4^-$ ions which are relatively readily available to plants are fixed by iron, aluminium and manganese compounds. Phosphorus can be additionally fixed by clay minerals in acidic soil reactions, and it also occurs in the form of insoluble calcium phosphates in alkaline conditions (Buckman, Brady, 1971). Some phosphorous compounds can stay in the soil for a long time. Once phosphorus has been introduced to the soil, it undergoes vertical and horizontal migration to a small extent, and it does not leave the soil in a gaseous form (Leonardi et al., 1999).

Sources of anthropogenic phosphorus in the soil include: 1) human and animal faeces deposited on the surface of an inhabited area, as witnessed in all primeval and some modern societies; 2) deceased bodies and the bones and meat of dead animals; 3) animal faeces applied as agents fertilising the soil and 4) phosphorus fertilisers used in modern agriculture (Brzeziński et al., 1983; Holliday, Gartner, 2007).

The objective of this paper is to indentify traces of shepherding activity on the basis of the content of different forms of phosphorus in the polonina mountain meadow soils based on the example of the Carynska Polonina situated in the Western Bieszczady in the Eastern Carpathians.

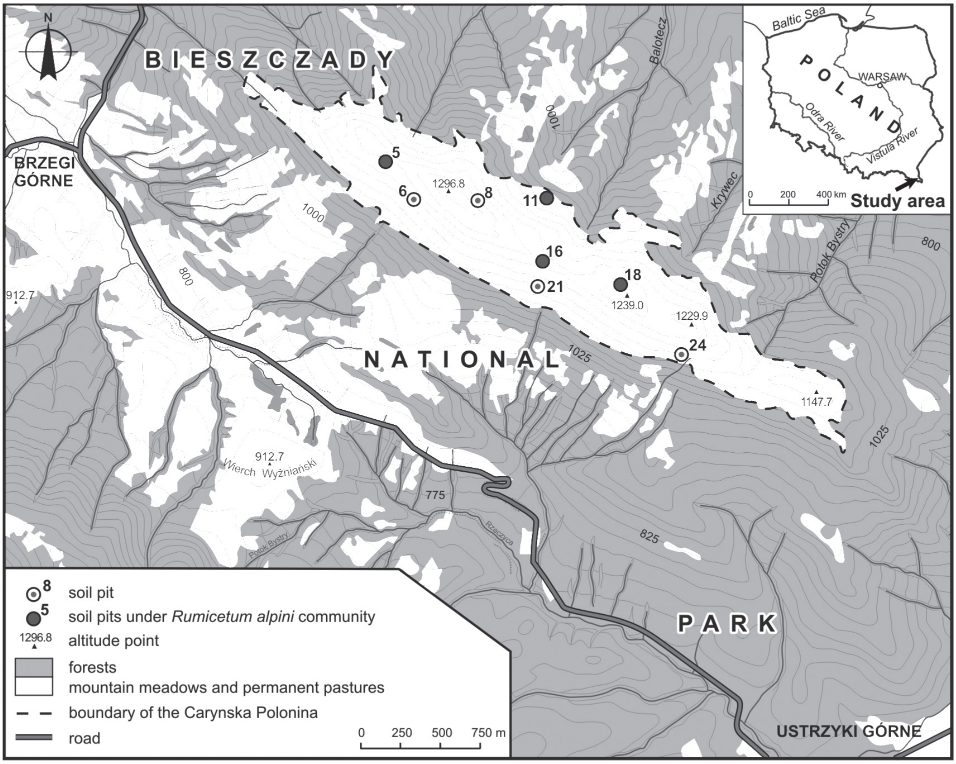

Fig. 1. Distribution of soil pits investigated in the Carynska Polonina.

Study area and site locations

Research was conducted in the area of the Carynska Polonina (49°08' N, 23°37' E) located within the Bieszczady National Park in Poland (Fig. 1). The Carynska Polonina is situated in the Western Bieszczady, being a part of the Eastern Beskids which form the first segment of the outer Eastern Carpathians (Kondracki, 1998). The study area is composed of flysh rocks which are mainly palaeogene otryt thick-bedded sandstones (Ślączka, Żytko, 1979). These flysh sandstones constitute the parent materials of the examined soils of the Carynska Polonina (Table 1), while the otryt sandstone outcrops form a polonina ridge and attain 1296.8 m a.s.l. at their highest level.

The greatest area of the Bieszczady National Park falls within a moderately-cool climatic belt with an average annual air temperature from +4 to +6 °C. The average annual total precipitation increases with height, and this exceeds 1200−1300 mm in the highest part of the Bieszczady (Nowosad, 1995).

A characteristic feature of the Bieszczady plant cover is its specific vertical zonality, which is manifested by the lack of an upper montane and a lowered upper tree line at an altitude of approximately 1100 m a.s.l. on the Carynska Polonina. According to Zarzycki (1963) the form of the upper forest line in the Bieszczady at an altitude of 1060 to 1180 m a.s.l. is mostly of an agricultural nature.

Mountain meadows above the upper forest line form the poloninas. Although it remains common opinion that this polonina belt was shaped by natural factors, human agricultural impact has had a crucial influence here on the range and structure of plant communities.

T a b l e 1. Location and brief description of the research sites.

Profile No.	Location	Geology	Soil unit (WRB 2006/2007)
Profiles under *Rumicetum alpini* community*			
5	1225 m a.s.l., gentle slope, SW exposure	Otryt thick-bedded sandstones	Haplic Cambisol (Siltic)
11	1085 m a.s.l., gentle slope, NE exposure		Haplic Cambisol (Humic)
16	1225 m a.s.l., moderate slope, NE exposure		Haplic Cambisol (Humic, Dystric, Sitlic)
18	1230 m a.s.l., ridge location		Cambic Umbrisol (Anthric)
Profiles under *Poo-Deschampsietum* community*			
6	1185 m a.s.l., steep slope, SW exposure	Otryt thick-bedded sandstones	Cambic Umbrisol (Humic)
21	1150 m a.s.l., moderate slope, SW exposure		Haplic Cambisol (Siltic)
24	1150 m a.s.l., steep slope, SW exposure		Haplic Cambisol (Humic, Dystric, Siltic)
Profile under *Calamagrostietum arundinaceae* community*			
8	1250 m a.s.l., steep slope, NE exposure	Otryt thick-bedded sandstones	Haplic Cambisol (Humic, Dystric)

Note: * Name of plant communities according to Skiba and Winnicki (1995).

The three plant communities of *Rumicetum alpini*, *Poo-Deschampsietum* and *Calamagrostietum arundinaceae* occurred in localities of pedological research (Table 1). In general, the *Rumicetum alpini* community occurred on slopes with a slight or medium gradient and NE or SW exposure. The prevailing species of this community was *Rumex alpinus* L. with a lesser number of *Deschampsia caespitosa* (L.) P. B e a u v. and *Utrica dioica* L. Under the *Rumicetum alpini* community the profiles 5, 11, 16, 18 were performed at altitudes from 1085 to 1230 m a. s.l. (Fig. 1). The prevailing species of the *Poo-Deschampsietum* community was *Deschampsia caespitosa* (L.) P. B e a u v. To a much lesser extent this community also includes *Festuca airoides* L a m., *Vaccinium myrtillus* L. and *Vaccinium vitis-idaea* L. Generally, the *Poo-Deschampsietum* community occurred on strongly inclined slopes with a SW exposure. Under the planes of this community, profiles 6, 21, 24 were performed at altitudes from 1150 to 1185 m a.s.l.. The predominant species of the *Calamagrostietum arundinaceae* community was *Calamagrostis arundinacea* (L.) Roth with a lesser proportion of *Vaccinium myrtillus* L. and *Vaccinium vitis-idaea* L. This community was based on a strongly inclined slope with NE exposure, where profile 8 was performed at an altitude of 1250 m a.s.l.

Material and methods

The examined material was collected in eight soil profiles. The first four analysed profiles, numbered 5, 11, 16 and 18, occurred under the *Rumicetum alpine* community, and shepherding activity was most likely undertaken here. The remaining four profiles were performed in places where flora did not indicate human interference. Profiles 6, 21 and 24 came under the *Poo-Deschampsietum* community and profile 8 was under the *Calamagrostietum arundinaceae* community. According to the IUSS Working Group WRB classification of 2006/2007, the following soils were examined; (1) profiles 5, 8, 11, 16, 21 and 24 were Cambisols with a morphology of A-Bw-C or A-Bw1-Bw2-BC and (2) profile 6 and 18 were Umbrisols with a morphology of A1-A2-Bw-C (Tables 1, 2). Soil samples were collected from individual genetic horizons, dried in the open air and strained through a 1mm mesh sieve. The following characteristics were determined in these samples; (1) the colour in both dry and moist states according to Munsell Soil Color Charts (1994), (2) the particle size distribution using Casagrande'a hydrometer method with Prószyński

T a b l e 2. The basic properties of the Carynska Polonina soils.

Prof. No.	Horizon	Depth cm	Munsell colour dry	Munsell colour moist	Skeleton > 1 mm %	Particle size distribution (%) 1–0.1 mm	0.1–0.05 mm	0.05–0.02 mm	0.02–0.005 mm	0.005–0.002 mm	< 0.002 mm	pH 1 M KCl	C org %	Ha cmol(+)·kg^{-1}	TEB cmol(+)·kg^{-1}	CEC cmol(+)·kg^{-1}	BS %
Profiles under *Rumicetum alpini* community																	
5	A	0–16	10YR 5/3	10YR 3/3	1.0	19.0	8.0	18.0	29.0	11.0	15.0	3.65	4.57	20.70	2.59	23.29	11.12
	Bw	16–34	10YR 6/3	10YR 4/4	3.0	17.0	5.0	16.0	30.0	15.0	17.0	3.90	2.28	14.55	1.51	16.06	9.40
	BC	34–55	10YR 7/4	10YR 5/4	23.0	17.0	6.0	18.0	24.0	15.0	20.0	4.00	0.85	10.20	2.34	12.54	18.66
11	A	0–11	10YR 4/2	10YR 3/2	15.0	35.0	8.0	20.0	23.0	6.0	8.0	3.65	4.84	21.75	1.21	22.96	5.27
	Bw	11–32	10YR 6/3	10YR 4/4	21.0	31.0	11.0	15.0	20.0	10.0	13.0	4.00	1.94	11.70	0.67	12.37	5.42
	BC	32–59	10YR 7/4	10YR 5/6	23.0	34.0	9.0	14.0	19.0	6.0	18.0	4.20	1.26	8.70	0.67	9.37	7.15
16	A	0–13	10YR 4/2	10YR 2/2	1.0	16.0	4.0	25.0	32.0	11.0	12.0	3.50	8.64	28.15	2.72	30.87	8.81
	Bw1	13–25	10YR 6/4	10YR 4/4	1.0	11.0	4.0	15.0	31.0	21.0	18.0	3.90	3.20	18.00	0.72	18.72	3.85
	Bw2	25–42	10YR 7/4	10YR 5/4	1.0	12.0	5.0	11.0	31.0	19.0	22.0	4.00	1.96	13.12	0.63	13.75	4.58
	BC	42–70	10YR 7/6	10YR 5/6	2.0	10.0	5.0	10.0	29.0	19.0	27.0	4.10	1.20	11.43	1.16	12.59	9.21
18	A1	0–12	10YR 3/2	10YR 2/1	9.0	31.0	6.0	20.0	22.0	9.0	12.0	3.50	8.29	27.56	1.30	28.86	4.50
	A2	12–24	10YR 3/3	10YR 2/2	10.0	34.0	7.0	20.0	27.0	5.0	7.0	3.70	6.33	24.94	0.86	25.80	3.33
	Bw	24–40	10YR 5/4	10YR 3/4	17.0	31.0	11.0	15.0	22.0	10.0	11.0	4.00	3.26	16.35	0.65	17.00	3.82
	BC	40–49	10YR 6/4	10YR 4/6	32.0	31.0	12.0	15.0	20.0	10.0	12.0	4.20	2.08	12.30	0.54	12.84	4.21
Profiles under *Poo-Deschampsietum* community																	
6	A1	0–5	10YR 4/3	10YR 3/2	14.0	35.0	12.0	30.0	15.0	4.0	4.0	3.50	5.67	26.75	1.08	27.83	3.88
	A2	5–21	10YR 4/4	10YR 3/3	7.0	36.0	20.0	17.0	18.0	6.0	3.0	3.86	3.84	14.85	0.50	15.35	3.26
	Bw	21–40	10YR 5/3	10YR 4/4	6.0	37.0	15.0	18.0	19.0	6.0	5.0	4.20	1.83	9.37	0.27	9.64	2.80
	BC	40–63	10YR 6/4	10YR 5/4	14.0	43.0	13.0	14.0	15.0	9.0	6.0	4.30	1.40	8.17	0.26	8.43	3.08
21	A	0–11	10YR 4/2	10YR 2/2	18.0	20.0	5.0	31.0	31.0	8.0	5.0	3.50	7.71	44.40	0.62	45.02	1.38
	Bw	11–34	10YR 6/4	10YR 5/4	20.0	8.0	15.0	20.0	29.0	16.0	12.0	4.00	1.02	13.95	1.13	15.08	7.49
	BC	34–48	10YR 7/3	10YR 5/6	33.0	13.0	8.0	14.0	28.0	17.0	20.0	4.15	1.51	10.35	0.83	11.18	7.42
24	A	0–9	n.o.*	n.o.*	11.0	20.0	8.0	33.0	24.0	5.0	10.0	3.70	5.75	27.00	2.04	29.04	7.02
	Bw1	9–22	10YR 5/3	10YR 3/3	7.0	18.0	8.0	22.0	33.0	11.0	8.0	3.80	4.11	16.87	0.69	17.56	3.93
	Bw2	22–35	10YR 6/3	10YR 3/4	4.0	21.0	7.0	20.0	35.0	10.0	7.0	4.00	3.27	13.50	0.59	14.09	4.19
	BC	35–70	10YR 7/4	10YR 5/3	9.0	21.0	7.0	19.0	26.0	12.0	15.0	4.20	1.66	10.68	0.43	11.11	3.87
Profile under *Calamagrostietum arundinaceae* community																	
8	A	0–8	10YR 4/3	10YR 3/3	8.0	34.0	22.0	15.0	21.0	4.0	4.0	4.02	3.70	16.50	0.30	16.80	1.79
	Bw	8–25	10YR 5/4	10YR 3/4	9.0	45.0	11.0	13.0	19.0	7.0	5.0	4.20	2.26	12.75	0.21	12.96	1.62
	BC	25–67	10YR 6/6	10YR 4/6	13.0	46.0	14.0	13.0	16.0	7.0	4.0	4.30	1.50	9.15	0.24	9.39	2.56

Note: * not determined.

modification[1] (Ostrowska et al., 1991), (3) soil pH in 1 M KCl solution (1:2.5 soil:solution ratio) measured electrometrically using a pH meter, (4) the content of organic carbon (C org) by the Tiurin procedure (Ostrowska et al., 1991), and (5) hydrolytic acidity (Ha) in a solution of 0.5 M $(CH_3COO)_2Ca$ by the Kappen titration method (Lityński et al., 1976), (6) the base exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were determined in 1 M CH_3COONH_4 as described by Ostrowska et al. (1991) and their sum as total exchangeable bases (TEB) was calculated. Exchangeable cations were determined by atomic absorption spectrophotometry (AAS) using a Perkin-Elmer 3300 apparatus. The cation exchange capacity (CEC) was calculated as the sum of H^+ (as Ha) and TEB, and the base saturation (BS) was established as the ratio of TEB to CEC, (7) total phosphorus (P_2O_5_t), inorganic phosphorus (P_2O_5_in) and organic phosphorus (P_2O_5_org) were determined by the Kuo (1995) procedure, (8) phosphorus extracted with 1% citric acid (P_2O_5_ac) was determined by the Van Reeuwijk procedure (1995). Citric acid extracts from soil phosphate ions absorbed by carbonate molecules and hydrated aluminium and iron oxides (Fotyma et al., 1987), where the phosphorus soluble in citric acid is described as available phosphorus (Holliday, Gartner, 2007).

Results

Basic properties of the studied soils

The basic properties of Carynska Polonina soils are presented in Table 2. The grain-size distribution of polonina soils is mainly silt loam as in profiles 5, 16, 21 and 24, sandy loam as in profiles 6 and 8 and loam seen in profiles 11 and 18. The reaction of the soils examined is generally strongly acidic regardless of the plant community concerned, and this is particularly evident in humus horizons A which exhibits a pH of 3.50–4.02. The value of this reaction increases with depth, reaching a maximum value of pH 4.30 in horizons BC

The highest content of organic carbon (C org) was recorded in humus horizons A, particularly in profile 16 (8.64% C org) and profile 18 (8.29% C org) under the *Rumicetum alpini* community (Table 2). The content of organic carbon (C org) decreased with depth. The highest content of H^+ ions (Ha) was observed in humus horizon A in profile 21 (44.40 $cmol(+)\cdot kg^{-1}$) under the *Poo-Deschampsietum* community (Table 2). Similar to the content of C org, the number of H^+ ions decreased with depth in the profile of these studied soils.

Humus horizons A are distinguished by possessing the highest cation exchange capacity (CEC—Table 2). A distinctive feature of these soils is the very low degree of base saturation (BS), regardless of the community in which they occur. The low degree of base saturation in some soils in this region, especially in acid brown soils, has been emphasized by Uziak (1963) and Skiba et al. (1998).

The content and distribution of different phosphorus forms found in the profile

The highest content of all the analyzed forms of phosphorus were recorded in humus horizons A (Fig. 2). This profile distribution of phosphorus in mountain soils was also reported by Zech et al. (1987) and Makarov (1998).

[1] In order to comply with the international standard, the name of textural classes was provided pursuant to USDA (Soil Survey Staff, 1975) based on the conversion algorithm according to Prusinkiewicz et al. (1994).

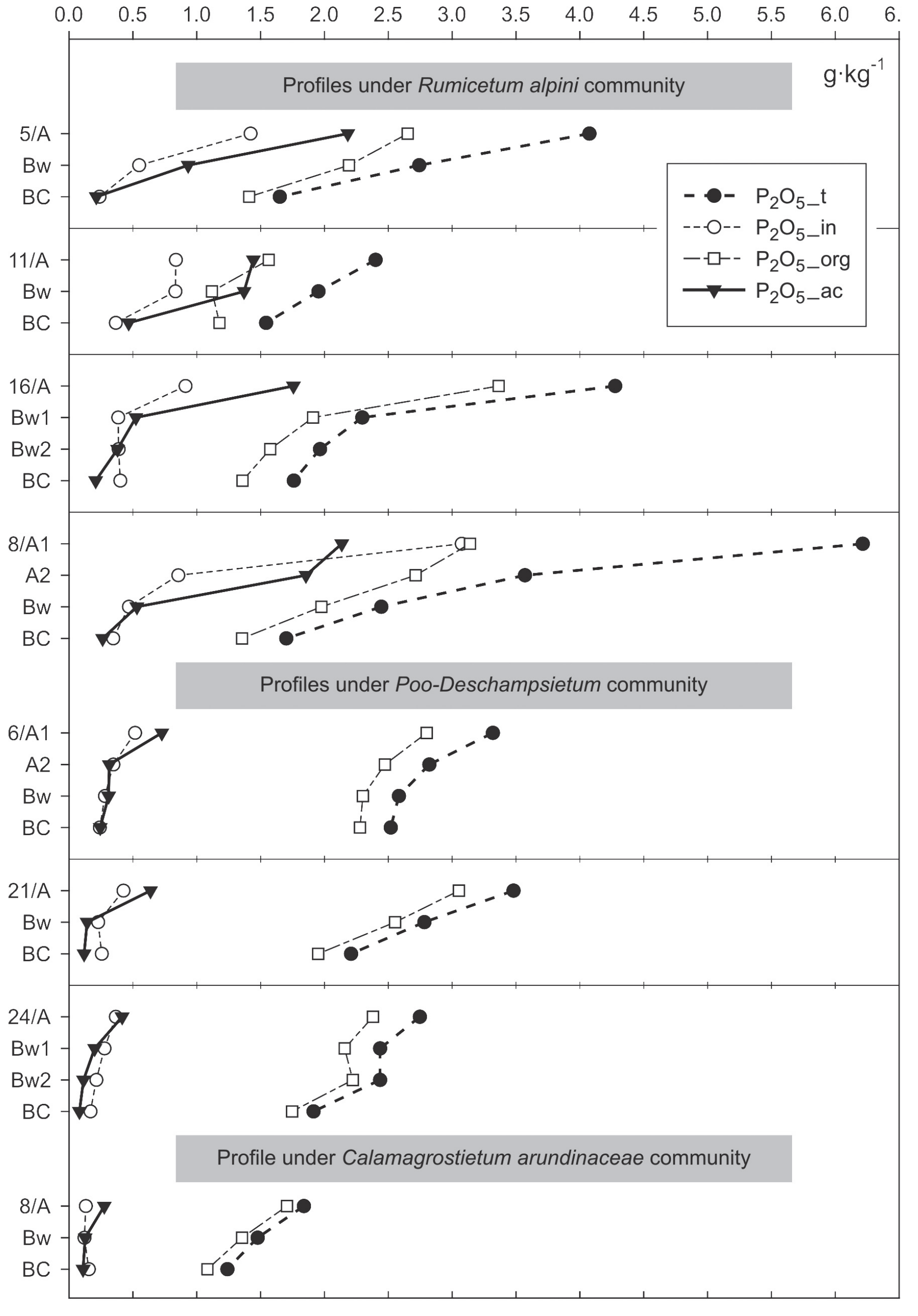

Fig. 2. The content of various forms of phosphorus in selected soils of the Carynska Polonina.

The content of total phosphorus (P_2O_5_t) in the Carynska Polonina soils is particularly high in soils under *Rumicetum alpini* (Fig. 2). This fairly substantial content of P_2O_5_t in soils of the flysh Carpathians is also mentioned by Wondrausch (1960).

The soil material examined is characterized by a content of organic phosphorus (P_2O_5_org) higher than the inorganic phosphorus (P_2O_5_in). The amount of P_2O_5_org decreases with depth, similar to the content of organic carbon (C org). A relationship between the content of P_2O_5_org and the amount of humus in the soils of the Caucasus was also indicated by Makarov et al. (1997). The predominance of organic phosphorus (P_2O_5_org) over inorganic phosphorus (P_2O_5_in) is typical under conditions of at least partly inhibited biological activity (Wondrausch, 1960). Under conditions of mountain climate, due to the considerable precipitation (high humidity) and low air temperature, the mineralisation processes and organic matter accumulation moderate (Cassagne et al., 2000). This leads to a considerable predominance of P_2O_5_org over P_2O_5, and this regularity was confirmed in the research of Makarov (1998). Tate and Newman (1982) reported in their examination of mountain soils in New Zealand that low pH combined with a cold climate reduces the microbiological decomposition of organic matter.

The content of phosphorus soluble in 1% citric acid (P2O5_ac) is the highest in humus horizons A which is located in the *Rumicetum alpini* community (profiles 5, 11, 16 and 18) and this content fluctuated between 1.44 and 2.18 $g \cdot kg^{-1}$ (Fig. 2). In soil profiles numbers 6, 21 and 24 in the *Poo-Deschampsietum* community and also in profile 8 of the *Calamagrostietum arundinaceae* community, the content of this form of phosphorus is considerable lower, and it does not exceed 0.73 $g \cdot kg^{-1}$ P_2O_5_ac in humus horizons A.

Discussion

One of the problems in interpreting results herein is the determination of a lower limit of phosphorus content for soil horizons enriched with this element as a result of human activity. According to the 2006/2007 IUSS Working Group classification (WRB), the anthropogenic Anthric horizon should contain at least 1.5 $g \cdot kg^{-1}$ P_2O_5 soluble in 1% citric acid. Despite existing quantitative criteria determining the content of phosphorus in soil horizons modified by humans, the geochemical background of the content of this element should be determined every time in soils located in the direct vicinity, even if these are located beyond former anthropopression (Griffith, 1980; Parnell et al., 2002; Bednarek, 2008).

By applying this IUSS Working Group WRB criterion (2006/2007) regarding the content of phosphorus soluble in 1% citric acid, it should be noted the phosphorus content soluble in 1% citric acid (P_2O_5_ac) in the *Rumicetum alpini* community humus horizons A of soil profiles 5, 16 and 18 is higher than 1.5 $g \cdot kg^{-1}$, and in profile 11 the content of P_2O_5_ac approximates this value at 1.44 $g \cdot kg^{1}$ (Fig. 2). At the same time, it must be stressed that in addition to the phosphorus content, the colour, the appropriate content of organic carbon and its thickness (which must equal at least 20 cm according to the IUSS Working Group WRB, 2006/2007) are significant criteria in distinguishing the Anthric horizon. Having considered the above-mentioned criteria, it should also be mentioned that the Anthric horizon occurs in profile 18.

In soil profiles 6, 21 and 24 of the *Poo-Deschampsietum* community and profile 8 of the *Calamagrostietum arundinaceae* community, a considerably lower content of phosphorus P_2O_5 was recorded compared to soils of the *Rumicetum alpini* community. A lower content of inorganic phosphorus (P_2O_5_in) and total phosphorus (P_2O_5_t) was also recorded in these soils (Fig. 2).

The research herein indicates that the most useful indicator of anthropopression is phosphorus extracted in 1% citric acid (P_2O_5_ac), and that the inorganic phosphorus (P_2O_5_in) and total phosphorus (P_2O_5_t) can be regarded as relatively useful indicators. It appears that the organic phosphorus (P_2O_5_org) is the least useful indicator of anthropopression, because the amounts in profiles 6, 21, 24 and 8 unaltered by humans are generally higher than in profiles 5, 11, 16 and 18 which are affected by humans (Fig. 2). However, Schlezinger and Howes (2000) reached a different conclusion, reporting a greater utility of organic phosphorus in an old Indian settlement. In contrast, Griffith (1980) in the study of an archaeological site previously inhabited by Huron Indians in Ontario, Canada, expounded the view that inorganic and organic phosphorus are both valuable tools.

A very interesting issue also concerns the determination of the periods in which the Carynska Polonia soils underwent anthropogenization. It has been estimated that settlement in Bieszczady began 30–40 thousand years ago, and the strong inflow of the Vlach shepherd population in the 14th century initiated pasturing on the meadows there (Marcinek, 2001). Periods of increased and decreased population occurred successively until the 19th century while the poloninas constituted manorial or communal pastures (Augustyn, 2000). The intensity of anthropopression on the natural environment of the Carynska Polonina was diverse and it was strongly connected with increased population and economic development of localities situated in its direct vicinity, i.e. Brzegi Górne (former Berehy Górne) and Ustrzyki Górne (Fig. 1). It appears that periods of increased human activity in this area occurred between 1489 and 1666 and also during 1773–1910 and 1911–1939 (Augustyn, 2000). The shepherds' exploitation in the poloninas ended in approximately 1940, and a process of natural plant community development began. However, this human agricultural impact considerably influenced its distribution and structure.

Conclusion

1. The high content of phosphorus extracted in 1% citric acid (P_2O_5_ac) in soils of the *Rumicetum alpini* community most likely indicates places of past shepherding activity in this area, as exemplified by shepherd shelters and cattle accommodation. At the same time, P_2O_5_ac is the most useful indicator of anthropopression compared to other forms of phosphorus.
2. The impact of human activity on the natural environment of the Carynska Polonina has intensified several times, and the last phase of anthropopression connected with an

increase in population and economic development in this area. occurred in the first half of the 20th century, between 1911 and 1939 (Augustyn, 2000).

3. The content of organic phosphorus (P_2O_5_org) is normally several times higher than the content of inorganic phosphorus (P_2O_5_in), and this should be associated with a slowdown in mineralization processes in organic soil material under the specialized mountain climate conditions of quite high precipitation and low air temperature.
4. Finally, all the analyzed forms of phosphorus (P_2O_5_t; P_2O_5_in; P_2O_5_org; P_2O_5_ac) are mostly concentrated in the surface humus horizons A of the examined soils of the Carynska Polonina.

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