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Soil Genesis

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FRACTIONAL COMPOSITION OF HUMUS IN SELECTED FOREST SOILS IN THE KARKONOSZE MOUNTAINS**

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Abstract. This paper describes the fractions of humus compounds present in the organic and mineral horizons of the forest soils in the area of the Karkonosze Mountains. Soil profiles that represented the mountain Podzols and Dystric Cambisol were located on the northern slope along an altitude gradient from 890 to 1255 m a.s.l. Two soils were located under the spruce forest, and one in the subalpine meadow. Soil samples were taken both from the surface organic layers (the ectohumus layer) and from the mineral horizons. Fractionation of humus compounds was made using the modified Turin method. The soils had the texture of loamy sand and sandy loam, an acidic or strongly acidic reaction, low base saturation, and the predomination of aluminum among exchangeable cations. A significant increase in the fulvic fraction (Ia) with depth in the soil profiles was observed that confirmed the high mobility of this fraction in the acid mountain soils, higher in the forest soils, and lower in the meadow soils. The content of fraction I decreased generally with depth in the soil profile; however, a secondary increase was observed in an illuvial Bh horizon of the Podzols. Fulvic acids predominated over the humic acids and this predominance increased with depth in the soil profile. The ratio of the humic to the fulvic acids in fraction I in the ectohumus horizons was influenced by the composition of a biomass inflow. The C_{HA}:C_{FA} ratio had the highest values under a spruce forest compared to a mixed stand and a subalpine meadow. In the surface horizons of the forest soils, a predominance of humic over fulvic acids was always observed, while in the subalpine meadow soils, the fulvic acids predominated over the humic acids in all soil horizons. Based on this study, it can be stated that the vegetation type and the dominant soil-forming process rather than simply climate factors influence the fractional composition of humus in the mountain soils of the Karkonosze Mountains.

In the Karkonosze, environmental condition and local habitats change clearly with an increasing altitude above sea level due to a change in the climate that results both in forest and soil zonal occurrence [3]. However, an altitudinal

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zonation of the vegetation in the Karkonosze Mountains is somewhat different than that in other European mountains, due to the influence of two environmental factors: north-oceanic air masses advecting to the Karkonosze and small massif upheaval [25].

The lower zone of the mountain spruce forest ranges in altitude from 500 to 1000 m a.s.l. At these altitudes, the natural vegetation, including an acidic mountain beech forest, was replaced by humans with spruce monocultures due to the faster timber production [10]. Currently, 'artificial' spruce stands predominate on the habitats of the poor ('acid') mountain beech forest. As a result of spruce propagation, a fundamental alteration in the floristic composition of the communities took place. The species typical in the deciduous forests were superseded, and coniferous forests or species not connected to forest ecosystems occurred in their place [3]. From the altitude of about 1 000 to 1 250 m a.s.l. the upper zone of the mountain spruce forest occurs in the Karkonosze. These communities are in the Sudeten Mountains relatively little transformed and probably are mostly of natural origin. According to the floristic issues, it is classified to poorer communities; only the vegetation of the forest floor is quite differentiated. The forest is declining gradually by tree dwarfing, and thus a 150 m -broad transition zone (ecotone) occurs above the altitude of about 1200 m a.s.l. The ecotone zone is gradually transformed into a dwarf mountain pine zone [10].

The composition of humus in the soils of the Sudeten Mountains has been the subject of numerous studies, particularly in the period of the forest decline [6], while currently only a few papers have been published concerning mainly relations between the environmental factors and the fractional composition of humus in the mountain soils.

The subject of the present study was a quantitative analysis of the humus in the soils of the Karkonosze Mountains, located at various altitudes above sea level and under different vegetation, based on the physical-chemical soil properties and the fractionation of the humus compounds.

RESEARCH AREA AND METHODS

The study included 3 soil profiles located in the eastern part of the Karkonosze, in the Karpacz region, at various altitudes and in differentiated habitat conditions. Two profiles were located under spruce forests, while one, for comparison, on a mountain meadow.

Profile No. 1 – altitude 1255 m a.s.l.: former pasture with compact cover of a moderate height turf vegetation (*Deschampsia caespitosa, Agrostis capillaries, Festuca rubra, Polygonum bistorta, Homogyne alpina, Vaccinium myrtillus*); bedrock: granite; rain- and meltwaters stagnate seasonally in the upper part of the soil profile; soil classification [12]: Folic Cambisol (Humic, Dystric, Oxyaquic, Endoskeletic).

Profile No. 2 – altitude 1 200 m a.s.l.; upper zone of the mountain spruce forest; numerous windthrows; mosaic vegetation of the forest floor (patches of *Vaccinium myrtillus*, *Calamagrostis villosa*, clumps of *Deschampsia flexuosa*, *Homogyne alpina*, *Trientalis europaea*, *Galium anisophyllon*, ferns); bedrock: granite; soil classification [12]: Histic Albic Podzol (Oxyaquic, Endoskeletic).

Profile No. 3 – altitude 890 m a.s.l.; lower zone of the mountain spruce forest; birch and larch admixture in the stand; vegetation on the forest floor covers the entire surface (clumps of *Vaccinium myrtillus*, *Deschampsia caespitosa*, *Deschampsia flexuosa* accompanied by *Calamagrostis villosa*, *Luzula luzuloides*, *Melampyrum sylvaticum*, *Polytrichum commune*); bedrock: granite; soil classification [12]: Haplic Podzol (Endoskeletic).

The following determinations were made in the collected soil samples (in the fine earth fraction <2 mm): particle-size distribution using the sieve-hydrometer method, organic carbon content (TOC) – by the dry combustion method (using automated Strőhlein CS – MAT 5500 apparatus), pH in distilled water and 1M KCl - by the potentiometric method, total nitrogen (Nt) - by the Kjeldahl method using a Büchi analyser; exchangeable acidity (Kw) and exchangeable aluminium (Al^{+3}) - using the Sokołow method, exchangeable base cations (Ca^{+2}, Mg^{+2}, K^{+}, and Na^{+}) - by spectrophotometric method after sample extraction with ammonium acetate at pH 7. Fractionation of the humus was made using a modified Tiurin method [9] by separating the following operationally defined fractions of the humic substances:

– fraction Ia (fulvic) – humic substances extracted with 0.05 M H_2SO_4,
– fraction I – humic substances extracted by multiple soil treatment with 0.1 M NaOH,
– fraction II – humic substances extracted by an alternating soil treatment with 0.1 M H_2SO_4 and 0.1 M NaOH. This fraction was determined only in mineral horizons,
– nonhydrolyzing carbon (C_{nh}) – post-extraction residue composed of the non-humified organic materials in the ectohumus layer, and mainly of the humins and ulmins in the mineral horizons. This fraction was calculated as the difference:

$$C_{nh} = 100\% - (\%\ C_{fraction\ Ia} + \%\ C_{fraction\ I} + \%\ C_{fraction\ II})\ [\%]$$

The results of the study were elaborated statistically using STATISTICA 9 software. Pearson correlation coefficients were calculated for a normal distribution and their significance was determined at the level of p=0.05 with n=14.

RESULTS AND DISCUSSION

The examined soils had the texture of loamy sand and sandy loam with a considerable fine skeleton content (Table 1). Whole profiles were strongly acidic: the pH measured in 1 M KCl ranged from 2.7 to 4.0, and the lowest pH values were observed in the ectohumus layers. Irrespective of the location and soil

TABLE 1. PARTICLE-SIZE DISTRIBUTION ACCORDING TO THE CLASSIFICATION OF PTG [24] AND IUSS [12]

Mineral soil horizon	Depth (cm)	Particle size (mm) distribution (%)										Sum of fine earth fractions (%)			Texture class
		>2.0	2.0-1.0	1.0-0.5	0.5-0.25	0.25-0.1	0.1-0.05	0.05-0.02	0.02-0.005	0.005-0.002	<0.002	2.0-0.05	0.05-0.002	<0.002	
Profile 1 – Folic Cambisol, subalpine meadow, 1 255 m a.s.l.															
ABg	0-13	31	18	13	17	11	14	18	5	3	1	73	26	1	LS
Bwg	13-26	32	15	11	11	10	12	25	12	3	1	59	40	1	SL
Bw	26-63	36	13	10	10	10	12	25	15	4	1	55	44	1	SL
Profile 2 - Histic Albic Podzol, spruce forest, 1 200 m a.s.l.															
AEg	0-8	15	14	15	15	16	13	13	8	5	1	73	26	1	LS
Esg	8-16	10	16	18	18	17	12	8	5	5	1	81	18	1	LS
Bhsg	16-24	18	17	19	21	15	9	5	6	7	1	81	18	1	LS
Bsg	24-35	26	12	14	20	17	13	11	6	6	1	76	23	1	LS
Bs	35-55	25	15	12	21	20	11	10	6	4	1	79	20	1	LS
Profile 3 – Haplic Podzol, mixed spruce forest, 890 m a.s.l.															
AE	0-6	12	14	18	15	5	11	20	11	4	2	63	35	2	SL
Bs	6-30	19	20	12	12	8	12	21	10	3	2	64	34	2	SL
Bws	30-60	38	25	15	12	9	12	13	8	4	1	73	25	2	LS

type, an increase in the pH with depth was observed in the profiles. Such a strong acidic reaction of the soils in the Karkonosze Mountains is their natural feature conditioned by environmental conditions, as confirmed by Adamczyk *et al*. [1].

The exchangeable acidity in the soils was clearly dependent on the content of organic matter (Table 2) which was also confirmed in other mountain soils by Drozd *et al*. [6]. The acidity decreased uniformly down the soil profile (in profiles Nos 1 and 3), while in profile No. 2 the highest acidity was observed in the illuvial horizon Bhsg, above and below which the acidity was lower. The characteristic feature of the examined soils was a low cation exchange capacity and predominance of aluminum among the exchangeable cations. The sum of the exchangeable base cations in mineral horizons did not exceed 1.25 cmol (+) kg^{-1}, while the degree of base saturation was within the range of 8.7 to 27.1%, and generally increased with the depth and soil pH (except profile No. 2).

The combination of biotic and abiotic factors in the Karkonosze favours the formation of ectohumus in forest soils and the enrichment of the mineral horizons in the humus. The high content of the organic substances in the whole profile is presented in numerous papers devoted to forest soils as a feature characteristic for these soils [7, 13]. The examined ectohumus horizons contained similar amounts of organic carbon, ranging from 23.8% (profile No. 1) to 27.0% (profile No. 3). In mineral horizons, the content of organic carbon decreased gradually with depth (in profiles 1 and 3), or (as in profile No. 2) reached a minimum in the eluvial level - 0.92%, and then increased in the illuvial horizon to 3.87%. A relatively high content of organic carbon was also observed in the deepest horizons of the soil profiles – ranging from 0.84 to 1.25%. Similar amounts and a vertical distribution were noted by Laskowski [18] and Kowaliński *et al*. [17]. Maciaszek *et al*. [21] and Gonet *et al*. 11] noted that ectohumus, where the predominant plant residues are spruce and pine needles, usually has an acid reaction, high content of organic carbon, low content of organic nitrogen and wide C/N range reaching even the values of 50 or more. In the analyzed profiles, the ratio of C/N in ectohumus ranged from 16 to 28 and was wider in the mineral horizons, where values from 24 to 36 were calculated.

The contribution of the particular fractions of humic substances was analyzed separately in the ectohumus and in the mineral horizons. When analyzing the fractional composition of humus it may be noticed that a small contribution was represented by fraction Ia representing low-molecular organic compounds of the highest solubility and mobility (Table 3). The contribution of the Ia fraction in organic horizons was within the range of 1.3 to 7.0 % TOC, while in mineral horizons it was in the range of 3.5 to 45.3 % TOC, and in all analyzed profiles increased with the depth. This demonstrates the very high mobility of fraction Ia in the whole profile, irrespective of the kind of soil and the plant cover. The contribution of fraction Ia increased in the soil profile with a pH increase (r=0.77)

TABLE 2. PHYSICO-CHEMICAL PROPERTIES OF SOILS UNDER INVESTIGATION

Soil horizon	Depth (cm)	pH		TOC	Nt	TOC:Nt	Kw	Al^{3+}	Ca^{2+}	Mg^{2+}	K^+	Na^+	S	ECEC	BS
		H_2O	KCl	(%)			cmol(+) kg^{-1}								(%)
Profile 1 – Folic Cambisol, subalpine meadow, 1 255 m a.s.l.															
M	12-0	4.5	3.8	23.80	1.48	16	6.36	6.17	0.80	0.38	0.19	0.09	1.46	7.82	18.7
ABg	0-13	4.7	3.9	3.46	0.14	24	3.35	3.28	0.72	0.25	0.09	0.08	1.14	4.49	25.4
Bwg	13-26	4.7	3.9	1.37	n.d.	n.d.	2.79	2.68	0.64	0.24	0.08	0.07	1.03	3.82	27.0
Bw	26-63	4.7	4.0	0.84	n.d.	n.d.	2.31	2.25	0.56	0.23	0.04	0.03	0.86	3.17	27.1
Profile 2 - Histic Albic Podzol, spruce forest, 1 200 m a.s.l.															
Oh	10-0	3.7	3.1	27.00	1.65	16	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
AEg	0-8	4.1	3.4	2.97	0.12	26	4.48	4.40	0.80	0.25	0.04	0.07	1.16	5.64	20.6
Esg	8-16	4.1	3.4	0.92	n.d.	n.d.	3.36	3.29	0.80	0.23	0.03	0.06	1.12	4.48	25.0
Bhsg	16-24	3.5	3.2	3.87	n.d.	n.d.	11.22	11.06	0.72	0.24	0.06	0.05	1.07	12.29	8.7
Bsg	24-35	4.3	3.7	2.45	n.d.	n.d.	6.06	6.01	0.70	0.22	0.04	0.06	1.02	7.08	14.4
Bs	35-55	4.4	3.9	1.03	n.d.	n.d.	2.34	2.30	0.56	0.22	0.03	0.06	0.85	3.19	26.6
Profile 3 – Haplic Podzol, mixed spruce forest, 890 m a.s.l															
Oh	2-0	3.5	2.7	26.80	0.969	28	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
AE	0-6	3.5	2.8	7.09	0.210	35	11.23	10.59	0.66	0.32	0.18	0.09	1.25	12.48	10.0
Bs	6-30	4.1	3.7	2.67	n.d.	n.d.	5.74	5.69	0.56	0.26	0.08	0.07	0.97	6.71	14.5
Bws	30-60	4.5	3.9	1.25	n.d.	n.d.	2.62	2.58	0.46	0.23	0.04	0.05	0.78	3.40	22.9

TOC – total organic carbon, Nt – total nitrogen, Kw - exchangeable acidity, S – sum of exchangeable cations, ECEC – effective cation exchangeable capacity (ECEC=Kw+S), BS – base saturation, n.d. – not determined.

TABLE 3. FRACTIONAL COMPOSITION OF HUMUS. ALL FRACTIONS WERE SHOWN IN PERCENT OF THE TOTAL ORGANIC CARBON (TOC)

Soil horizon	Fraction Ia	Fraction I				Fraction II				CHA I+II	CFA I+II	CHA/CFA I+II	Cnh
		C-extracted	CHA	CFA	CHA: CFA	C-extracted	CHA	CFA	CHA: CFA				
	(% TOC)					(% TOC)				(% TOC)			
Profile 1 – Folic Cambisol, subalpine meadow, 1 255 m a.s.l.													
M	7.0	48.0	23.8	24.2	0.98	n.d.	n.d.	n.d.	n.d.	23.8	24.2	0.98	45.0
ABg	18.0	36.0	17.4	18.7	0.93	1.9	1.0	0.9	1.11	18.4	19.6	0.94	44.1
Bwg	33.2	28.9	11.6	17.3	0.67	3.9	3.0	0.9	3.33	14.6	18.2	0.80	34.0
Bw	37.7	20.6	7.7	12.9	0.60	5.2	1.8	3.4	0.53	9.5	16.3	0.58	36.5
Profile 2 - Histic Albic Podzol, spruce forest, 1 200 m a.s.l.													
Oh	1.3	46.6	31.4	15.2	2.06	n.d.	n.d.	n.d.	n.d.	31.4	15.2	2.07	52.1
AEg	4.3	38.6	26.2	12.3	2.13	2.4	1.6	0.8	2.00	27.8	13.1	2.12	54.7
Esg	9.6	44.7	25.7	19.0	1.35	1.9	1.5	0.4	3.75	27.2	19.4	1.40	43.8
Bhsg	12.7	48.9	28.3	20.2	1.40	4.8	3.2	1.6	2.00	31.5	21.8	1.44	33.6
Bsg	29.4	28.3	10.9	17.4	0.63	1.5	0.8	0.7	1.14	11.7	18.1	0.65	40.8
Bs	45.3	15.7	6.4	9.3	0.69	1.9	0.9	1.0	0.90	7.3	10.3	0.71	37.1
Profile 3 – Haplic Podzol, mixed spruce forest, 890 m a.s.l													
Oh	1.5	51.7	27.3	24.4	1.12	n.d.	n.d.	n.d.	n.d.	27.3	24.4	1.12	46.8
AE	3.5	41.6	26.7	14.9	1.80	3.1	2.2	0.9	2.44	28.9	15.8	1.83	51.8
Bs	17.3	44.1	19.9	24.1	0.83	4.5	3.1	1.4	2.21	23.0	25.5	0.90	34.1
Bws	42.3	22.0	8.9	13.1	0.68	3.5	2.6	0.9	2.88	11.5	14.0	0.82	32.2

CHA – carbon of humic acids, CFA – carbon of fulvic acids, Cnh - nonhydrolizing carbon, n.d. – not determined.

and base saturation (r=0.66), and inversely to a decrease in total organic carbon content (r=-0.62) and total nitrogen (r= -0.57) (Table 4). The contribution of fraction Ia in deeper soil horizons under spruce forests in the Karkonosze has also been observed by Kowaliński *et al*. [17], Drozd [5], Drozd *et al*. [4, 6, 7], as well as by Niemyska-Łukaszuk [22], and Niemyska-Łukaszuk and Miechówka [23] in forest and meadow soils of the Tatra Mountains, which suggests a dependence on the climate. Based on the present study and the results of the mentioned authors, it may be concluded that the high contribution of fraction Ia was connected to the strongly acidic reaction of the soils and presence, at least periodically, of an excessive humidity in the upper layers of the soil profile. Both factors favour mobilization and relocation of the low-molecular humic substances. Attention should also be paid to the fact that differentiation in the contribution of fraction Ia in profiles Nos 2 and 3 is similar – from about 4% to over 40% of TOC, which confirms the podzolization in both profiles. Another possible explanation of both the overall tendency and a gradual change in the contribution of fraction Ia in the central section of the profiles is the polygenetic character of numerous mountain soils, which was suggested by Kabała *et al*. [15, 16]. In a subalpine Cambisol (profile No. 1), the vertical differentiation of the contribution of fraction Ia is slightly lower than in other profiles (from 7.0 to 37.7% of TOC), similar to minimal pH differentiation in the whole profile. This is accompanied by the lack of podzolization features, despite the location in the most humid and cool altitude zone.

The most important group among the humus compounds was fraction I, defined classically as the organic compounds easily bonding with calcium and with the non-silicate forms of sesquioxides. However, in the analyzed mountain soils, strongly acidic and poor in calcium, fraction I should be defined

TABLE 4. COEFFICIENTS OF CORRELATION BETWEEN THE HUMUS FRACTIONS AND SOIL PROPERTIES

Variable	Depth	pH	TOC	Nt	S
Fraction Ia	0.98*	0.77*	-0.62*	-0.57*	0.12
Fraction I - C extr.	-0.85*	-0.70*	0.62*	0.54*	-0.13
Fraction I - CHA	-0.86*	-0.80*	0.59*	0.54*	-0.17
Fraction II - C extr.	0.53	0.33	-0.74*	-0.75*	0.35
Fraction II - CHA	0.33	0.19	-0.69*	-0.71*	0.37
CHA I+II	-0.83*	-0.79*	0.50	0.45	-0.13
CFA I+II	-0.41	-0.19	0.35	0.25	0.04
C- non-extracted	-0.74*	-0.60*	0.51	0.52	0.13

*Statistically significant at $p<0.05$, n = 14. Other symbols explained in Tables 2 and 3.

operationally, *i.e.* as a fraction extracted with a specified reagent in the given conditions. Such an understood fraction includes the group of low-molecular humic acids easily extracted with the weak alkaline solution. The contribution of this fraction reflects the current direction and intensity of the soil forming processes. In the ectohumus horizons, the contribution of fraction I was within the range of 46.6-51.7% of TOC, while in mineral horizons it has usually been lower, in the range of 15.7 to 48.9% of TOC (Table 3). In a soil without any morphological symptoms of podzolization, as in profile No. 1, the contribution of fraction I decreased gradually down the soil profile. In the podzolized soils (as in profiles Nos 2 and 3), the contribution of that fraction was clearly lower in mineral surface horizons, and the maximum was reached in the illuvial Bhsg horizon. A decrease in the contribution of fraction I was always accompanied by a very low contribution of fraction Ia – below 5%, which demonstrated the occurrence of an eluvial process. The contribution of fraction Ia was significantly negatively related to soil pH (r = -0.70) and significantly positively related to the organic carbon (r = 0.62). This is the typical distribution of fraction I in the forest soils formed from granite, as observed already by Laskowski [18] in the Sudetes Mountains, Niemyska-Łukaszuk [22] in the Tatra Mountains, and Drozd *et al*. [4, 6, 7], Licznar *et al*. [19, 20] in the Karkonosze Mountains. The ratio of the humic to fulvic acids (C_{HA}/C_{FA}) extracted in fraction I changed significantly in the soil profiles with depth. In the soil profile No. 1 (Cambisol), the ratio of C_{HA}/C_{FA} decreased from 0.98 to 0.60, and in profile No. 2 (Podzol) of from 2.06 to 0.69, pointing to the essential inversion of fractions ratio within the profile. The relative increase in the fulvic acids contribution with depth reflects the vertical segregation in the soil profiles caused by the stronger binding of the humic acids in surface layers and fulvic fraction movement to the underlying horizons. The relative increase in the contribution of the fulvic acids of fraction I with depth was clearly correlated with a similar increase in the contribution of the fulvic acids of fraction Ia. A relative balance between the humic and fulvic fraction was observed in ectohumus horizons, both on the pasture in a subalpine zone, and under a mixed stand in the lower forest zone, whereas a predominance of the humic fractions was found in ectohumus under the spruce forest. Profile No. 2 featured the considerable predominance of spruce needles as an ectohumus building material, while in profile No. 1 it was grass material, and in profile No. 3 - shrub-grassy with an addition of birch leaves and spruce needles. The high predominance of the humic above fulvic acids in an ectohumus of soil under the spruce forests has already been noticed by other authors, *e.g.* Drozd *et al.* [6]. There is, however, lack of a convincing explanation in the literature as to why a higher amount of high-molecular connections is formed in an ectohumus formed of spruce needles, when compared to the material of a mixed composition. 'Needle' ectohumus in profile No. 2 is characterized by the highest content of nitrogen (Table 2), which may be the key to explaining the results of the microbiological transformations of residual organic matter. Dziadowiec [8] reveals that in 'deciduous' beddings, humification is characterized rather by a predominance of the formation of fulvic acids, while in 'coniferous' beddings a relative balance between C_{HA} and C_{FA} is usually created.

The contribution of fraction II, defined as a stable connection with silicates, was small and did not exceed 5.2% of TOC. Such a low content of this fraction probably resulted from the scant amount of clay (1-2%) with which the fraction forms stable mineral-organic complexes [6, 20]. The percentage of fraction II was variable in the examined profiles. In the subalpine Cambisol (profile No. 1) the contribution of fraction II – in contrast to the fraction I – increased clearly with depth, mainly due to an increase in fulvic fraction contribution. However, due to the small contribution of fraction II, the sum of C_{HA} I + II and the sum of C_{FA} I + II decreased uniformly in the profile and this was also accompanied by a gradual loss in the contribution of non-hydrolysing carbon (Table 3). Such an arrangement is very typical for the brown earths (Cambisols), where weathering processes are accompanied by an *in situ* stabilization in the surface and subsurface horizons. The only distinguishing feature of the analyzed mountain soils is the very low C_{HA}/C_{FA} I + II index, reaching a value of 0.58, which indicates the large mobility of the fulvic acids in the strongly acidic soils. In forest soils (profiles Nos 2 and 3), the contribution of fraction II was the highest in subsurface horizons B due to an accumulation of the humic fraction. In both profiles of forest soils, the sum of humic acids (CHA I + II) and fulvic acids (CFA I + II) decreased down the profile, however, with distinct fluctuations in surface and subsurface mineral horizons, pointing to the less or more advanced podzolization of these soils.

The very high contribution of nonhydrolysing carbon, not only in ectohumus layers, but also in surface mineral horizons, reaching even 54.7% of TOC, indicated a slow rate of humification in these soils and the high percentage of non-decomposed organic debris, besides the already formed humins and ulmins [29]. A rapid increase in the amount of non-hydrolysing carbon in lower parts of profile no. 2 (up to 40.8% of TOC) can be explained by the bi-partial structure of the slope covers and also, as mentioned above, the polygenetic character of the Podzols in the upper zone of the Karkonosze Mountains.

CONCLUSIONS

1. The contribution of the low-molecular humus compounds (fraction Ia) increases in the soil profile with depth, which confirms their high mobility in acid mountain soils, higher in the forest soils, and lower in the meadow soils.

2. The contribution of fraction I decreases generally from the surface down the soil profile, but in soils subjected to podzolization it increases in illuvial Bh horizons. The relative predominance of the fulvic over humic acids in that fraction increases with depth.

3. The composition of a biomass inflow influences the ratio of the humic and fulvic acids of fraction I in ectohumus horizons. The ratio of C_{HA}/C_{FA} reaches the highest values under a monoculture spruce forest.

4. In the surface horizons of the forest soils, a predominance of humic over fulvic acids is always observed, while in the subalpine meadow soils, fulvic acids predominate over humic acids in all horizons of the soil profile.

5. Vegetation type and the dominant soil-forming process rather than simply climate factors influence the fractional composition of humus in the mountain soils of the Karkonosze Mountains.

REFERENCES

[1] Adamczyk B., Baran S., Borkowski J., Komornicki T., Kowaliński S., Szerszeń L., Tokaj J.: Karkonosze Polskie. Zakład Narodowy im. Ossolińskich, Wrocław, 77, 1985.
[2] Borkowski J., Szerszeń L., Kocowicz A.: Karkonosze. Przyroda nieożywiona i człowiek. Wyd. UW, Wrocław, 353, 2005.
[3] Danielewicz W., Raj A., Zientarski J.: Ekosystemy leśne Karkonoskiego Parku Narodowego. Wyd. Karkonoskiego Parku Narodowego. Jelenia Góra, 96, 2002.
[4] Drozd J., Licznar S.E., Licznar M.: Zesz. Probl. Post. Nauk Roln., **411**, 149, 1993.
[5] Drozd J.: Zesz. Probl. Post. Nauk Roln., **418**, 347, 1995.
[6] Drozd J., Licznar M., Weber J., Licznar S.E., Jamroz E., Dradrach A., Mastalska-Cetera B., Zawerbny T.: Degradacja gleb w niszczonych ekosystemach Karkonoszy i możliwości jej zapobiegania. Monografia PTSH, Wrocław, 125, 1998.
[7] Drozd J., Licznar M., Licznar S.E., Weber J.: Zesz. Probl. Post. Nauk Roln., **464**, 281, 1998.
[8] Dziadowiec H.: Rozkład ściółek w wybranych ekosystemach leśnych. Uniwersytet Mikołaja Kopernika, Toruń, Rozprawy, 137, 1990.
[9] Dziadowiec H., Gonet S.: Prace Komisji Naukowych PTG, **120**, 1, 1999.
[10] Fabiszewski J.: Karkonosze Polskie. Wyd. Ossolineum, Wrocław, 535, 1985.
[11] Gonet S., Dębska B., Zaujec A., Banach-Szott M., Szombathowa N.: Pol. Tow. Subst. Humus, Wrocław, 61, 2007.
[12] IUSS: World Soil Resources Report 103, FAO, Rome, 122, 2006.
[13] Jamroz E.: Sylwan, **153**(10), 684, 2009.
[14] Kabała C.: Zesz. Probl. Post. Nauk Roln., **418**(1), 361, 1995.
[15] Kabała C., Bogacz A., Waroszewski J., Ochyra S.: Roczn. Glebozn., **49**(1), 90, 2008.
[16] Kabała C., Waroszewski J., Szopka K., Bogacz A.: Roczn. Glebozn., **61**(4), 78, 2010.
[17] Kowaliński S., Drozd J., Licznar S.: Roczn. Gleboz., **24**(1), 145, 1973.
[18] Laskowski S.: Roczn. Glebozn., **24**(1), 57, 1973.
[19] Licznar S.E., Mastalska-Cetera B.: Geoekologiczne Problemy Karkonoszy, **1**, 217, 1997.
[20] Licznar S.E., Łabaz B., Licznar M.: Opera Corcontica, **37**, 486, 2000.
[21] Maciaszek W., Gruba P., Lasota J., Lato J., Wanic T., Zwydak M.: Wyd. AR Kraków, 69, 2001.
[22] Niemyska-Łukaszuk J.: Roczn. Glebozn., **28**(1), 169, 1977.
[23] Niemyska-Łukaszuk J., Miechówka A.: Zesz. Probl. Post. Nauk Roln., **411**, 167, 1993.
[24] Polish Society of Soil Science: Roczn. Glebozn., **60**(2), 5, 2009.

[25] R a j A.: Karkonoski Park Narodowy. Wyd. Olsztyn, 96, 2001.
[26] S k i b a S., D r e w n i k M.: Karkonoskie Badania Ekologiczne, I Konferencja, Dziekanów Leśny, Oficyna Wyd. IE PAN, 93, 1994.
[27] S k i b a S., D r e w n i k M., S z m u c R.: Karkonoskie Badania Ekologiczne, II Konferencja, Dziekanów Leśny, Oficyna Wyd. IE PAN, 125, 1994.
[28] S k i b a S., D r e w n i k M., S z m u c R.: Zesz. Probl. Post. Nauk. Roln., **418**(1), 353, 1995.
[29] T u r s k i R.: Roczn. Glebozn., **22**(1), 19, 1971.

SKŁAD FRAKCYJNY PRÓCHNICY WYBRANYCH GLEB LEŚNYCH KARKONOSZY

Celem przedstawionej pracy była ocena ilościowa próchnicy górskich gleb Karkonoszy zróżnicowanych pod względem położenia nad poziom morza i występującej szaty roślinnej w oparciu o właściwości fizykochemiczne gleb i skład frakcyjny związków próchnicznych. Badaniami objęto 3 profile glebowe zlokalizowane we wschodniej części Karkonoszy, w rejonie Karpacza, na różnych wysokościach oraz w zróżnicowanych warunkach siedliskowych. Dwa profile zlokalizowane zostały w ekosystemach leśnych, natomiast jeden dla porównania, w strefie ekotonowej, w ekosystemie łąkowym. W pobranych próbkach gleb oznaczono: skład granulometryczny, zawartość węgla organicznego, pH, zawartość azotu ogółem, kwasowość wymienną oraz glin wymienny, wymienne kationy zasadowe oraz skład frakcyjny związków próchnicznych zmodyfikowaną metodą Tiurina. Na podstawie przeprowadzonych badań stwierdzono, że udział niskocząsteczkowych połączeń próchnicznych (frakcja Ia) zdecydowanie rośnie w profilu glebowym wraz z głębokością, co potwierdza ich dużą mobilność w kwaśnych glebach górskich, większą w glebach leśnych, a mniejszą w glebach łąkowych. Udział frakcji I (wolnej), zmniejsza się w głąb profili, ale w glebach podlegających bielicowaniu wzrasta w poziomach wzbogacenia Bh. Wraz z głębokością rośnie względna przewaga kwasów fulwowych nad huminowymi tej frakcji. Skład dopływającej biomasy wpływa na proporcję kwasów huminowych i fulwowych frakcji I w poziomach ektopróchnicy. Proporcja C_{HA}:C_{FA} przyjmuje najwyższe wartości pod monokulturowym borem świerkowym. W powierzchniowych poziomach gleb leśnych zawsze występuje przewaga kwasów huminowych nad fulwowymi, natomiast w glebie brunatnej pod murawą subalpejską kwasy fulwowe dominują nad huminowymi we wszystkich poziomach genetycznych profilu glebowego. Nie tyle strefowość klimatyczna, co charakter zbiorowiska roślinnego oraz dominujący proces glebotwórczy wpływają na skład frakcyjny związków próchniczny w profilach górskich gleb Karkonoszy.