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MUTUAL RELATIONS BETWEEN SOIL COVER AND PLANTS IN MOUNTAINOUS HUMID CLIMATIC CONDITIONS

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A b s t r a c t: Specific, humid climate of mountain areas has a great influence on the properties of soils and vegetation, as well as on the mutual relations between these inseparable elements of ecosystems. Research on the interdependence between soils and natural vegetation was carried out on the mountain meadows of the Bieszczady National Park. In conditions of the cooler and more humid mountain climate the peculiar character of the soils lies in the presence of organic surface horizon of properties varying considerably from the properties of deeper mineral horizons. This horizon is of great importance in the protection of scarce elements. It prevents pollutants from reaching the ecosystem. It influences the soil water economy. It prevents erosion. This buffer element of the mountain soils requires special protection - in the Bieszczady Mountains the erosion of the mountain meadow soils is only noticeable where the covering vegetation and the organic surface soil horizon were destroyed, e.g. on tourist tracks. The plants of the Bieszczady mountain meadows, together with their direct product - the organic surface soil horizon, prevents the chemical erosion of the mountain meadows, reducing the leaching of many biogenous elements, e.g. calcium.

K e y w o r d s: the Bieszczady Mts., mountain meadows, soil-plant relations, chemical composition.

INTRODUCTION

Soil, a fundamental and primary element of terrestrial ecosystems, functions properly only in mutual relation with covering vegetation. In the conditions of humid climate of mountain areas soil must develop many buffer mechanisms protecting against water erosion, eolian erosion and the so-called chemical erosion (excessive and quick leaching of many elements in conditions of great total rainfall and eminent acidification of the environment). The system of protective and buffer mechanisms could not function properly without mutual relations with the

covering vegetation adapted to the specific character of the ecosystem, and which is in some sense a product of the soil.

The properties of the Bieszczady mountain meadows were the subject of research carried out by Uziak [8,9], Skiba *et al.* [6,7], Woźniak [10,11]. The interdependence between these inseparable elements of terrestrial ecosystems - soils and plants - were also studied by the following: Adamczyk [1], studying the environment of Gorce; Malicki [3], studying the environment of Carpathian Flysch; Skiba and Winnicki [6], analysing the Bieszczady mountain meadows; Woźniak [10], paying special attention to interdependence in chemical composition of soils and plants of the Bieszczady mountain meadows.

As Kostuch and Kopeć [2] say, the importance of persistent grasslands in the water economy of the mountains consists in the following: increasing the retention of rainfalls by meadow sward, changing surface flows into gravitational flows, improving the water retention of soils by the structure-forming activity of the rhizosphere, protecting the soils against water and eolian erosion, cleaning activity of the soil contributing to the decrease of fluvial water eutrophication, protecting against contamination of the water environment. Also Starkel [7] indicates the significant role of a plant covering in forming water conditions of mountain areas and in reducing erosion.

MATERIALS AND METHODS

The research was carried out on the Bieszczady mountain meadows. In the years 1991-1993 the properties of acid brown soils and the chemical composition of the prevailing plant species were examined. Soil samples were collected from all the horizons of acid brown soils from the area of noticeable succession of arborescent vegetation into the fragments of the Bieszczady mountain meadows on a higher plane. The research was also extended by the analysis of the floral composition, made by the Brown-Blanquet method. It should be emphasised that the plant material for chemical analyses was collected directly from the soil pit.

Among other things, the following physical and chemical properties of the soils were studied after the samples had been dried to air dry condition: pH KCl and pH H_2O by the potentiometric method, granulometric composition by the areometric method acc. to Casagrande as modified by Prószyński, organic carbon content by the Tiurin's method. The content of calcium was determined by the spectrophotometry of atomic absorption, after the soil samples had been mineral-

ized in $HClO_4$, and the plants samples in HNO_3, $HClO_4$ and H_2SO_4, in proportion 20:5:1, respectively.

RESULTS AND DISCUSSION

The properties of the analysed Bieszczady meadows acid brown soils - in the form of the range of changes of the properties under examination - were presented in an earlier publication [10]. The profiles, situated near the top of Bukowe Berdo and Mała Rawka and presented in Tables 1 and 2, allow for detailed analysis of

Table 1. Granulometric compoition of researched soils - some selected profiles of mountain meadows acid brown soils (Bieszczady Mts.)

Localization and number of profile	Horizon	Depth (cm)	Fraction content in % diameter (mm)			
			1.0-0.1	0.1-0.02	<0.02	<0.002
Bukowe Berdo 2	Ofh	0-2	organic matter			
	Ah	2-12	49	38	13	6
	Bbr	12-29	52	34	14	8
	BbrC	29-(44)	53	24	23	6
Bukowe Berdo 3	Ofh	0-2	organic matter			
	Ah	2-15	38	47	15	7
	Bbr	15-47	34	41	25	10
	BbrC	47-(61)	32	31	37	12
Bukowe Berdo 4	Ofh	0-2	organic matter			
	Ah	2-12	26	49	25	9
	Bbr	12-39	24	50	26	8
	BbrC	39-(57)	27	33	40	14
Bukowe Berdo 5	Ofh	0-3	organic matter			
	Ah	3-20	18	56	26	8
	Bbr	20-41	17	41	42	11
	BbrC	41-(81)	13	20	67	20
Mała Rawska 6	Ofh	0-3	organic matter			
	Ah	3-16	42	42	16	8
	Bbr	16-51	33	40	27	10
	BbrC	51-(64)	33	35	32	6
Mała Rawska 7	Ofh	0-1	organic matter			
	Ah	1-16	22	44	34	11
	Bbr	16-47	22	33	45	13
	BbrC	47-(79)	17	19	64	26

Table 2. Reaction and C-organic content in some selected profiles of researched mountain meadows acid brown soils (Bieszczady Mts.)

Localization and number of profile	Horizon	Depth (cm)	pH		C-organic content (g kg^{-1} d.m.)
			H_2O	KCl	
Bukowe Berdo 2	Ofh	0-2	3.7	3.2	278
	Ah	2-12	4.0	3.1	59
	Bbr	12-29	4.4	3.6	38
	BbrC	29-(44)	4.5	3.9	28
Bukowe Berdo 3	Ofh	0-2	4.5	3.5	325
	Ah	2-15	3.9	3.4	58
	Bbr	15-47	4.3	3.6	40
	BbrC	47-(61)	4.3	3.9	25
Bukowe Berdo 4	Ofh	0-2	4.0	3.6	259
	Ah	2-12	4.4	3.6	56
	Bbr	12-39	4.4	3.8	47
	BbrC	39-(57)	4.4	3.9	35
Bukowe Berdo 5	Ofh	0-3	3.9	3.5	381
	Ah	3-20	4.3	3.5	82
	Bbr	20-41	4.3	3.6	41
	BbrC	41-(81)	4.5	3.8	25
Bukowe Berdo 6	Ofh	0-3	3.9	3.5	477
	Ah	3-16	4.1	3.3	103
	Bbr	16-51	4.2	3.6	49
	BbrC	51-(64)	4.4	3.8	27
Bukowe Berdo 7	Ofh	0-1	3.4	2.9	303
	Ah	1-16	4.0	3.6	52
	Bbr	16-47	4.5	3.9	32
	BbrC	47-(79)	4.5	3.9	14

the changeability of some chosen properties in the whole soil profile. In each case the same profiles were analysed (Tables 1, 2 and 4) and the vegetation directly connected with them (Tables 3 and 4).

The Bieszczady mountain meadows acid brown soils are almost always characterised by the presence of organic matter accumulated on the surface. The genesis of this horizon was the subject of the analysis carried out by Uziak [9], and its characteristics were described in detail by Skiba *et al.* [5]. The depth of this horizon is generally small; in the profiles presented in the Tables, it falls within 1 and 3 cm. The degree of organic matter decomposition is varied, so the content of organic carbon in this horizon is also changeable (Table 2). The presence of organic matter accumulated on the surface is of great importance in the conditions of the

T a b l e 3. Plant cover of mountain ash brushwoods (*Sorbus aucuparia* L. em. Hedl.), with regard to plant species coverage - Bieszczady mountain meadows (Brown-Blanquet method)

Specification	Date 21.07.1998 Localization						Degree of plant species coverage
	Bukowe Berdo				Mała Rawka		
Successive No. of record	2	3	4	5	6	7	
Area of record (m^2)	60	80	80	60	50	80	
Density of shrub (B) layer (%)	25	50	70	5	75	5	
Cover of herbs (C) layer (%)	80	70	70	100	80	95	
Number of species in record	14	17	16	10	10	14	
1	2	3	4	5	6	7	8
Sorbus aucuparia	+	3	3	1	4	1	2466.7
Almus viridis	2	1	2	.	.	.	666.7
Acer pseudoplatanus	.	r	r	.	.	.	3.3
Rubus ideaus	+	1	1	.	.	.	175.0
Rubus sp.	.	.	1	.	.	.	83.3
Vaccinium myrtillus	1	+	2	3	4	1	2133.3
Vaccinium vitis idea	.	.	.	.	r	.	1.7
Calamagrostis arundinacea	2	3	3	1	1	3	2333.3
Deschampsia caespitosa	3	2	.	3	.	1	1625.0
Luzula multiflora	+	+	+	1	.	1	191.7
Rumex acetosa	+	1	1	.	.	+	183.3
Festuca ovina	+	.	.	1	.	1	175.0
Senecio fuchsii	1	+	+	+	.	+	116.7
Potentilla erecta	+	.	.	+	+	1	108.3
Gentiana asclepiadea	1	+	r	+	r	.	103.3
Polygonum bistorta	.	.	+	1	.	.	91.7
Rumex alpestris	1	+	.	.	.	.	91.7
Dryopteris dilatata	.	r	1	.	.	.	85.0
Hypericum perforatum	.	+	.	.	+	+	25.0
Melampyrum hemorosum	.	.	+	.	+	r	18.3
Campanula patula	+	+	.	.	.	.	16.7
Viola reichenbachia	.	.	.	.	r	+	10.0
Athyrium distentifolium	.	.	+	.	.	.	8.3
Calamagrostis villosa	.	+	.	.	.	.	8.3
Galeopsis speciosa	.	+	.	.	.	.	8.3
Silene vulgaris	.	.	+	.	.	.	8.3
Trientalis europaea	.	.	.	.	.	+	8.3
Trisetum flavescens	.	.	.	.	.	+	8.3
Maianthemum bifolium	.	.	.	.	r	.	1.7

Table 4. Total content of Ca in acid brown soils and plants of Bieszczady mountain meadows (mg kg^{-1} d.m.)

Specification	Bukowe Berdo Profile No. 3	Mała Rawka Profile No. 6
Soil:		
horizons: Ofh	2112	3084
Ah	706	326
Bbr	228	210
BbrC	195	167
Plants:		
Forest bluejoint (*Calamagrostis arundinacea*)	1301	1477
Blueberry (*Vaccinium myrtillus*):		
stems	4618	5953
leaves	7192	7226
fruits	1482	1544

humid climate of mountain areas, especially on steep slopes. This choice of climate and biosphere, characterised by properties incomparable to the mineral horizons lying deeper, is of importance in preventing water erosion and eolian erosion. In the High Bieszczady Mountains clear symptoms of erosion were not found on the mountain meadows; it is noticeable only in the areas devoid of this protective layer, i.e. well-trodden tourist tracks. Thus, the product of biosphere and humid mountain climate conditions fulfils the conditions of the duration of mountain meadows ecosystems, by nature devoid of the protective arborescent vegetation covering. This horizon is characterised by significantly higher sorption and buffer capacities than the mineral horizons [4]. The above-mentioned authors state also that the developed sorption properties of this horizon fulfil the function of a protective filter for soils of the mountain meadows.

The analyses carried out by the author, concerning the chemical composition of the Bieszczady mountain meadows soils [11] showed that the surface horizons are the site where soluble forms of biogenous elements accumulate, which in conditions of a humid climate and soil acidification are subject to leaching from the soil profile. For example, the presence of calcium, a scarce element in acid brown soils of the mountain meadows under examination [10] may be even several times higher in surface organic horizons than in the corresponding mineral horizons [11]. A similar picture of interdependence is presented by the chosen profiles (Table 4): living plants accumulate the most Ca; it is also accumulated in decayed organic matter, many times richer in Ca than the mineral horizon. Slow decomposition of organic

matter reaching the soil helps to retain the amount of biogenous elements even in very acidified soils.

The acid brown soils of the Bieszczady mountain meadows are characterised by granulometric composition of loamy soils, often with a significant participation of silt fraction (Table 1), already indicated in the earlier publication [10]. These soils are characterised by high variability of the granulometric composition even in rather shallow soil profiles (Table 1). Maybe it is also a result of transferring colloidal clay deeper into the soil, as well as the variability of the properties of mother rocks. The intensity of the leaching processes of some substances in the analysed soils is also indicated by the significant, and even high, content of organic carbon in the deepest horizons of the profile (Table 2).

Acid brown soils of the Bieszczady mountain meadows lie under natural grasses [5], they are also covered by non-forest blueberry communities [5]. In many places plant communities of the mountain meadows, as shown by the author's research, are characterised by the simultaneous occurrence of two, most common and often dominating, species of grasses: Forest bluejoint *(Calamagrostis arundinacea)* and Tussock grass *(Deschampia caespitosa)*, as well as Blueberry *(Vaccinium myrtillus)*. When examining the acid brown soils of the Bieszczady mountain meadows, in such places the soil pits were localised. Arborescent vegetation which penetrates into higher placed areas, as observed sometimes on the Bieszczady mountain meadows, is an interesting phenomenon; this concerns Mountain ash *(Sorbus aucuparia)* mainly. The floral composition presented in Table 3 refers to such fragments of Bukowe Berdo and Mała Rawka. It should be emphasised that the profiles presented in Tables 1 and 2 were localised exactly at the places where phytosociological records were taken. The present proliferation of trees and shrubs is undoubtedly of a natural character. The Bieszczady Mountains are mountains of exceptionally low top forest boundary. It is rather difficult to state now what was the role of man in its formation in the past, which means that the influence of climate and soil properties on this process is not easy to determine, either. Quoting the conclusions of Malicki [3], it seems, however, that wherever the ecotone sphere is formed by dwarfed and convoluted little trees of European beech *(Fagus silvatica)*, this boundary may be of natural character. On the other hand, wherever the ecotone sphere is formed by rather shapely beech trees or where the trees succession is evident today, the boundary was formed by anthropogenic factors (grazing, establishing hay-growing meadows, forest burning, deforestation).

Trees encroaching on areas lying higher indicate that both the properties of acid brown soils presented in Tables 1, 2 and 4, and the factor prevailing in mountain areas - climate conditions, enable the development of some species of trees above the present top forest boundary in the Bieszczady Mountains.

CONCLUSIONS

1. The structure of the profile of acid brown soils of the Bieszczady mountain meadows confirms the dominating role of climatic factors and vegetation cover in the process of creation and evolution of these soils, especially their surface organic horizons.

2. In conditions where the humid climate of mountain areas and the organic surface soil horizons fulfil exceptionally significant buffer and protective functions, they are, *inter alia*, a place of accumulation and protection of biogenous elements, e.g. calcium, preventing thus the chemical erosion of soils.

3. The greatest amounts of calcium are accumulated by leaves and stems of blueberry - multi-annual dwarf-shrub; the content of Ca is also high in organic horizons of soils, whereas it is many times lower in mineral horizons, where it clearly decreases with the depth of the profile. This element presents well the interdependence between the chemical composition of soils and vegetation in case of biogenous factor, prone to leaching.

4. Erosion on the Bieszczady mountain meadows is noticeable only where the soils were deprived of plant cover and organic surface horizon, e.g. on tourist tracks.

REFERENCES

1. **Adamczyk B.:** Studies on the development of relations between parent rock and soils. Part II. Forest soils formed on Flysch rocks of the Magura nappe in the Gorce Mts. Acta Agraria et Silvestria, Ser. Silv., VI, 3-46, 1966.
2. **Kostur R., Kopeć S.:** Importance of permanent grasslands in the water economy of mountains. Zesz. Probl. Post. Nauk Roln., 235, 165-175, 1980.
3. **Malicki M.:** Some notes on physiography of the Flysch Carpathians. Roczn. Glebozn., 13, 3-25, 1963.
4. **Skiba S., Drewnik M., Szmuc R., Prędki R.:** The buffering properties of the mountain grassland soils in the Western Bieszczady Mts. Roczn. Bieszczadzkie, 2, 193-199, 1993.
5. **Skiba S., Drewnik M., Prędki R., Szmuc R.:** Soils of the Bieszczady National Park. Monografie Bieszczadzkie, 2, 1-88, 1998.
6. **Skiba S., Winnicki I.:** Soil of the plant communities of the mountain meadows in the Bieszczady Mts. Roczn. Bieszczadzkie, 4, 97-109, 1995.
7. **Starkel L.:** Soil erosion versus water economy in the Carpathians. Zesz. Probl. Post. Nauk Roln., 235, 103-118, 1980.

8. **Uziak S.:** The origin and classification of mountain soils in the Flysch Carpathian. Roczn. Glebozn., 13, 56-71, 1963a.
9. **Uziak S.:** Brown soils of mountain regions, exemplified by soils of the Western Bieszczady. Ann. UMCS, E, 13, 37-54, 1963 b.
10. **Woźniak L.:** Organogenic metal elements and some toxic heavy metals in soils and plants of Bieszczady. Zesz. Nauk AR Kraków, Rozprawy, 216, 1-80, 1996.
11. **Woźniak L.:** Selected problems of elements cycling in Bieszczady mountain meadows environment. Zesz. Probl. Post. Nauk Roln., 464, 179-190, 1998.