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Forest habitats developed on alluvial soils in the area of mountains

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Abstract

The aim of our research was to present the properties of alluvial soils from mountain forest areas. Additionally, the paper presents the vegetation accompanying the studied soils. The detailed characteristics will include the stand and the undergrowth. 10 study plots representing mountain areas were included in the study. Study plots were located in the mountains in the Bielsko, Ustroń, Szklarska Poręba, Węgierska Górka forest districts as well as the Bieszczadzki, Babiogórski and Tatrzański National Parks. At each sample plot a detailed description of soil profile has been carried out, samples were collected from each genetic horizon in order to perform the basic determinations of the soil properties. On each research plot, a phytosociological relevé using the Braun-Blanquet method and a taxonomic description of the tree stand were performed. The diagnosis of forest site type was determined according to forest management principles and the Trophic Soil Index was calculated. The properties of mountain alluvial soils are related to the properties of the rock complexes within which alluvial terraces are formed. Mountain alluvial soils belong to various groups (Fluvisols, Leptosols, Cambisols, Phaeozems), which depend on the valley location and anthropogenic factors. River regulation and the disappearance of floods result in the formation of soils with a cambic horizon and acidification of the surface horizons devoid of the influence of water. Two main plant communities are associated with mountain alluvial soils: *Alnetum incanae* and *Carici remotae-Fraxinetum*. Ecosystems related to mountain alluvial soils are very valuable due to their high biodiversity and fulfilling various ecosystem functions.

1. Introduction

Alluvial soils are located in the floodplain valley of a river or stream. Alluvial soils made of river alluvia often contain gravel and stones that are clearly dumped. The skeletal nature of alluvial soils is closely related to the nature and course of the river. The most skeletal ones are the mountain alluvial soils. The lithology of deposits reflects the way the river bed has developed and the sedimentation conditions (Falkowski, 1971). Soils developed from river sediments (alluvials), called alluvial soils, are characterized by a wide variety of morphology and properties, resulting from the variability of the graining and mineral composition of alluvia, as well as differences in the content of organic matter (Polish Soil Classification, 2019). According to Kobierski and Banach-Szott (2022), the properties of humic acids in alluvial soils are determined by the quantity and quality of organic matter transported in suspension, which accumulates in flood valleys during floods each year. In the morphology of alluvial soils, there is a clear layering of the profiles caused by the application of successive layers of alluvia by flowing waters (Brożek and Zwydak, 2003). According to Kacprzak et al. (2012), the differentiation of the properties of soils developed on the Holocene river sediments of the San river terraces clearly refers to the position of the studied profiles in the terrace system, which is related to the length of the period of transformation of the original alluvial material and subject to modern flooding by the rising river.

The Classification of Forest Soils (2000) combines all alluvial soils into one type in which 4 subtypes are distinguished: initial (raw, MDi), ordinary (MDw), humous (MDp) and brown (MDbr) alluvial soils, which in the classification WRB (2022) corresponds to Coarsic Leptosols (Fluvic), Fluvisols, Phaeozems and Cambisols, respectively. The biogeochemical properties of alluvial soils allow for the distinction of hypertrophic, eutrophic and mesotrophic varieties. These are forest habitats of riparian forests and mountain riparian forests. Most of the alluvial soils form habitats for *Salici – Populetum* and *Alnetum incanae*. Sometimes, however, in the more stabilized part of the rivers create conditions for the *Carici remotae – Fraxinetum* and *Ficario – Ulmetum typicum* (Wanic et al., 2011). Alluvial soils in the forests occupy a small area and are managed, which often leads to their distortions and degradation. Soil degradation leads to a deterioration of the functionality of the soil ecosystem, thus threatening biodiversity (Coelho et al., 2004). Alluvial soils in the immediate vicinity of river ecosystems are often overexploited or mismanaged, which causes loss of ecosystem productivity and deteriorates vegetation composition (Rivera-Ferre et al., 2016; Rodrigo-Comino et al., 2021). The current type of use of alluvial soils significantly affects the properties of these soils, especially the amount of organic matter (Kobierski and Banach-Szott, 2022).

Little research has been conducted on alluvial soils in mountains forested areas. Our research tries to fill this gap. The aim of our research was to present the properties of alluvial soils from mountain forest areas. The study presents the basic physical and chemical properties of the tested alluvial soils. Additionally, the paper presents the vegetation accompanying the studied soils. The detailed characteristics will include the stand and the undergrowth.

2. Materials and methods

2.1. Study sites

10 study plots representing mountain areas were included in the study. Study plots were located in the mountains in the Bielsko, Ustroń, Szklarska Poręba, Węgierska Górka forest districts as well as the Bieszczadzki, Babiogórski and Tatrzański National Parks (Fig. 1 and 2; Table 1). The presented study material was collected during the projects carried out by the Soil Science Department at University of Agriculture in Krakow. The analyzed soils were located on flat alluvial terraces. The profile of the studied soils is developed from alluvial sediments containing a skeleton rounded by water (Fig. 2). We ruled out the presence of deluvilated sediments or colluvia in the profiles. At each sample plot a detailed description of soil profile has been carried out, samples were collected from each genetic horizon in order to perform the basic determinations of the soil properties. On each research plot, a phytosociological relevé using the Braun-Blanquet method and a taxonomic description of the tree stand were performed (Braun-Blanquet, 1932). Based on geological and soil characteristics, forest floor vegetation and species composition, the affiliation of each research plot to a type of forest habitat was determined. Classification of Forest Soils (2000) was used for description of soil profiles.

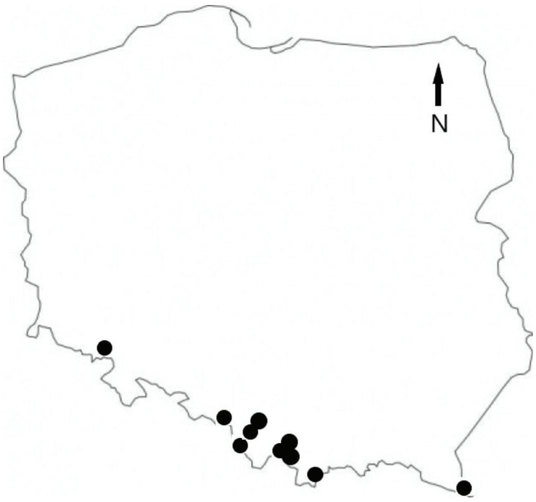

Fig. 1. Distribution of research plots in mountain region of Poland

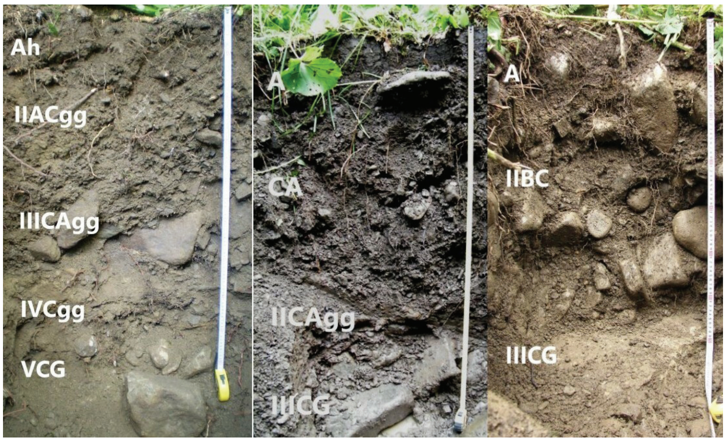

Fig. 2. Examples of alluvial soils from mountainous areas (BgPN1, BgPN2, PgPN3)

Table 1
Characteristics of research plots

Profile	Location of the alluvial terrace	**Altitude a.s.l.**	**Rock complex in the catchment area**	**Coordinates**
BgPN1	Marków Stream Valley	724	Hieroglyphic and Magura sandstones	49°36’24’’N 19°31’12’’E
BgPN2	Jaworzyna Stream Valley	730	Hieroglyphic and Magura sandstones	49°36’44’’N 19°33’04’’E
BgPN3	Rybny Stream Valley	694	Hieroglyphic and Magura sandstones	49°36’44’’N 19°32’22’’E
BsPN	Terebowiec Valley	675	Krosno sandstones	49°05’57’’N 22°39’29’’E
TPN	Białka Valley	1030	Granites and quartzites	49°14’58’’N 20°06’00’’E
G.Izer.	Mała Kamienna Valley	475	Granites and granitogneisses	50°51’26’’N 15°33’43’’E
BŚl1	Kameszniczanka Valley	530	Istebna sandstones	49°33’47’’N 19°01’22’’E
BŚl2	Leśnianka Stream Valley	570	Istebna sandstones	49°39’39’’N 19°03’27’’E
BŚl3	Leśnianka Stream Valley	520	Istebna sandstones and conglomerates	49°39’56’’N 19°04’51’’E
Pog.Śl	Puńcówka Stream Valley	360	Cieszyn sandstones and shales	49°42’48’’N 18°43’06’’E

2.2. Laboratory analysis

Basic physicochemical properties were determined in samples collected from the profile (Ostrowska et al., 1991). The texture was determined using laser diffraction (Analysette 22, Fritsch, Idar-Oberstein, Germany). The soil pH was determined in H_2O and KCl using the potentiometric method. Hydrolytic acidity (Y) was determined by the Kappen method. C and N were measured using an elemental analyzer (LECO CNS TrueMac Analyzer Leco, St. Joseph, MI, USA). The cation concentrations (Ca^{2+}, Mg^{2+}, K^+, Na^+) were determined after extraction in 1M ammonium acetate by inductively-coupled plasma analysis (ICP-OES Thermo iCAP 6500 DUO, Thermo Fisher Scientific, Cambridge, UK). Bulk density was determined using Kopecky cylinder in humus horizons. In other cases, the following formula was used to determine the bulk density: $D = 1.3773 * e^{-0.0547*x}$ (x – organic carbon content) (Brożek i Zwydak 2003). The diagnosis of forest site type was determined according to forest management principles (CILP, 2012). Moreover, the Trophic Soil Index (SIGg) was calculated (Brożek et al., 2015, 2016). The calculation of soil organic carbon stock (SOCS) to a depth of 100 cm was performed in accordance with the following formula:

$SOCS = C \cdot D \cdot m$ (Mg ha^{-1}),

where: C is organic carbon content in the genetic horizon (%), D is bulk density (g cm^{-3}), and m is a thickness of the horizon (cm).

2.3. Statistical analysis

Principal component analysis (PCA) was used in order to interpret factors in certain data sets. The Statistica 12 software (StatSoft 2012) was used for data analysis.

3. Results

The analyzed alluvial soils of the mountain area belong to different groups (Fig. 2). In the analyzed set of plots, all subtypes distinguished in the classification of forest soils in Poland were recorded, i.e.: MDw (profiles: BgPN3, TPN, BŚl2), MDbr (profiles: BsPN, G.Izer., BŚl1, Pog.Śl), MDp (BgPN1, BgPN2) and in one case MDi (BŚl3 profile). They are distinguished by the presence or absence of the enrichment horizon, the depth of the humus accumulation horizon as well as the depth of the soil profile and its grain size. The structure of the profile of the discussed alluvial soils in mountain areas is similar. As a rule, a mineral humus accumulation horizon of varying thickness (from 5 to 33 cm) develops on the surface, which passes into transitional horizons with the features of the parent rock with intensifying signs of gleyic processes (Cgg-CG). In the analyzed set of plots, the alluvial soil of the Izerskie Mountains are an exception in this respect, in the profile of which an organic overburden with the features of butvine was found on the plot (Table 2). In the case of MDbr profiles, the cambic horizon enrichment is visible between the humus-mineral horizon and the horizon of the parent rock, which is the result of drainage of the surface horizons of the soil profile. The grain size of the alluvial soils in the mountain area varies greatly. Alluvial sediments of river valleys and mountain streams are strongly rocky. Already in the humus accumulation horizons, there is an admixture of gravel and rock fractions in the amount of 5–40%, in the horizons of enrichment and bedrock the proportion of the skeleton fraction increases rapidly, reaching 60–95%. In the analyzed set, an exception is the alluvial soil of the Silesian Foothills (Pogórze Śląskie), formed in the sediments of the Puńcówka river, where the share of skeletal parts was the lowest (10–30% even in the deep horizons of the profile) (Table 2). The particle size distribution in the analyzed alluvial soils shows a large diversity, with the sandy fraction dominating, with a significant share of silt (usually up to 50%) and a small share of the clay fraction (usually below 10%). The most coarse-grained in the analyzed set are alluvial soils embedded in the complexes of granite rocks of the Izerskie Mountains (ps-pg) and alluvial soils of the Silesian Beskids area produced in the alluvials of the Istebna sandstone complexes (ps-pg-gp). More fine-grained are alluvial deposits in the BgPN Magura sandstone complexes, BsPN Krosno sandstones and Tatra granitogneisses (pg-gp-gz), while alluvial soils of the Silesian Foothills (gz-pyi) show the finest granulation (Table 2).

The organic carbon content in the humus-mineral horizons of the analyzed alluvial soils ranges from 2.15–6.25% with a favorable degree of decomposition as evidenced by the C/N ratio (9.7–15.3). Only in the case of the mentioned alluvial soil of the Izerskie Mountains area, an organic horizon (Of-Oh; butvine) was found on the surface (Table 2). The chemical characteristics of the analyzed alluvial soils are slightly different. They are generally slightly acid to neutral. In half of the cases, the surface humus accumulation horizon was more acidic (pH <5). In the case of two profiles (G.Izer., BŚl1), strong acidification covered the entire profile. In addition to the above-mentioned – more acidified profiles and levels of caries accumulation, the analyzed alluvial soils showed a high degree of saturation with alkaline cations, reaching 75–98% (Table 3). Only in one case (alluvial soil from Pogórze Śląskie) the presence of calcium carbonate in an amount not exceeding 2% was found.

For the analyzed alluvial soils the Trophic Soil Index was calculated. The total stock of fractions <0.02, exchangeable alkaline cations, acidity in the soil column with a cross-section of 1 m^2 and a depth of 100 cm was calculated; the total acidity was also compared to the fraction <0.02 (Yp) and the organic matter quality index (N^2/C) in the first mineral humus accumulation horizon was calculated (Table 4). The analyzed alluvial soils of the mountain area are characterized by the stock of fractions <0.02 (Zczs) amounting to 116 to 593 kg m^{-3} (on average it is 306 kg m^{-3}). The total stock of exchangeable cations (Z_S) in the analyzed pedons ranges from only 4 to 230 mol (+) m^{-3} (on average 103.4 mol (+) m^{-3}). Alluvial soil of the Izerskie Mountains shows an extremely low cation resource. In the case of the total amount of acid ions (Z_Y), the analyzed alluvial soils show less differentiation of this feature (20.1–77.4 mol (+) m^{-3} (average 42.8 mol (+) m^{-3}). The lowest amount of acidic ions were found in alluvial soil in Pogórze Śląskie, and the highest values of this characteristic were found in other MDbr produced in acidic rock deposits (G.Izer., BŚl, BsPN). The strongest acidification is shown by alluvial soil of the Izerskie Mountains, and the lowest by alluvial soil of the Silesian Foothills

Table 2
Properties of the analyzed alluvial soils (content of organic carbon, total nitrogen, available phosphorus and grain size)

Profile	Depth (cm)	Horizon	C	N	C/N	P	skeleton	sand	silt	clay	PTG 2008
BgPN1	0–15	Ah	4.11	0.33	12.6	3.5	0	61	29	10	gl
	15–45	IIACgg	1.33	0.10	12.8	3.1	40	69	22	9	gp
	45–60	IIICAgg	0.49	0.06	8.7	2.0	75	78	17	5	pg
	60–90	IVCgg				0.2	80	69	22	9	gp
	90–100	VGC				0.5	90	71	20	9	gp
BgPN2	0–13	A	4.02	0.27	15.1	2.8	10	45	43	12	gz
	13–85	CA	1.61	0.11	14.6	2.7	60	48	38	14	gz
	85–110	IICAgg	1.58	0.10	16.3	2.4	80	47	40	13	gz
	110–120	IIICG				1.2	90	55	34	11	gl
BgPN3	0–12	A	4.63	0.35	13.4	4.9	5	56	34	10	gl
	12–50	IIBC	0.85	0.09	9.0	2.4	50	77	17	6	pg
	50–70	IIICG				0.9	90	80	14	6	pg
BsPN	0–20	A	3.40	0.35	9.7	1.7	10	41	52	7	pyg
	20–65	ABbr	1.06	0.10	10.6	2.2	60	55	38	7	gp
	65–100	C				2.0	90	73	21	4	pg
TPN	0–17	A	4.87	0.35	13.9	8.3	5	46	29	25	gz
	17–35	C1	0.59	0.05	12.3	5.5	70	63	30	7	gp
	35–80	C2gg				2.4	80	66	28	6	gp
	80–120	CG				1.6	80	64	30	6	gp
G.Izer.	1–4	Of	31.89	1.30	24.5	44.7	0				
	4–6	Oh	24.45	1.20	20.4	25.2	0				
	6–40	BbrA	0.65	0.06	10.8	7.8	1	77	21	2	pg
	40–90	BbrC				14.7	60	91	7	2	ps
	90–150	C				10.2	90	86	12	2	ps
BŚl1	0–20	A	2.15	0.16	13.4	4.2	15	77	21	2	pg
	20–40	Bbr	0.58	0.05	12.3	3.7	30	77	20	3	pg
	40–85	Cgg				1.2	60	86	12	2	ps
	85–120	Gor				1.0	90	91	7	2	ps
BŚl2	0–24	A	3.06	0.20	15.3	5.7	0	52	44	4	gp
	24–50	AC	0.85	0.07	12.7	2.7	10	52	42	6	gp
	50–80	Cgg				1.4	30	58	36	6	gp
	80–110	CG				0.8	75	58	34	8	gl
BŚl3	1–5	A	6.25	0.50	12.5	9.6	40	83	14	3	pg
	5–10	CA	0.59	0.06	9.8	5.1	80	96	4	0	pl
	10–60	IIC				5.7	90	90	8	2	ps
	60–150	IIIC				4.1	95	81	12	7	pg
Pog.Śl	0–33	A	3.15	0.30	10.5	3.5	30	31	50	19	gz
	33–61	ABbr	0.95	0.11	8.6	0.9	5	33	50	17	gz
	61–77	BbrC				1.4	30	36	46	18	gz
	77–130	C				0.6	10	20	61	19	pyi

C – organic carbon (%), N – nitrogen content (%), P – available phosphorus content (mg kg^{-1}); skeleton, sand, silt, clay content (%), PTG2008 – granulometric group according to PTG2008 (pl – sand, ps – sand, pg – loamy sand, gp – sandy loam, gl – sandy loam, gz – loam, pyg – silt loam, pyi – silt loam)

Table 3
Properties of analyzed alluvial soils (pH, acidity and content of basic exchangeable cations)

Profile	Depth (cm)	Horizon	pH H_2O	pH KCl	Hh	Ca	K	Mg	**S**	**V(%)**
BgPN1	0–15	Ah	4.76	3.86	12.0	7.1	0.53	1.11	8.73	42
	15–45	IIACgg	6.22	5.21	3.0	8.6	0.19	0.91	9.74	77
	45–60	IIICAgg	7.06	6.06	1.3	7.4	0.18	0.69	8.29	87
	60–90	IVCgg	6.75	5.81	1.8	10.4	0.11	0.84	11.34	87
	90–100	VGC	7.10	6.12	1.3	9.2	0.19	0.94	10.40	89
BgPN2	0–13	A	6.14	5.32	3.9	15.2	0.33	2.11	17.65	82
	13–85	CA	6.49	5.49	2.5	11.7	0.18	1.57	13.45	84
	85–110	IICAgg	6.86	5.76	1.8	12.0	0.15	1.64	13.77	89
	110–120	IIICG	7.31	6.07	1.4	10.3	0.20	1.60	12.17	90
BgPN3	0–12	A	6.00	5.28	6.2	13.2	0.59	1.85	15.66	72
	12–50	IIBC	6.60	5.57	2.9	7.1	0.30	0.97	8.39	75
	50–70	IIICG	6.51	5.39	2.1	7.3	0.14	1.25	8.76	81
BsPN	0–20	A	4.90	3.70	15.0	7.0	0.29	1.37	8.66	37
	20–65	ABbr	6.00	5.10	2.5	7.7	0.09	1.09	8.90	78
	65–100	C	6.50	5.70	1.7	5.8	0.09	0.82	6.72	80
TPN	0–17	A	6.46	5.34	3.8	8.8	0.35	1.97	11.15	75
	17–35	C1	6.72	5.40	2.7	4.2	0.10	0.94	5.34	66
	35–80	C2gg	6.80	5.48	1.2	2.8	0.08	0.60	3.60	75
	80–120	CG	6.80	5.51	1.0	1.7	0.06	0.52	2.40	70
G.Izer.	1–4	Of	3.90	2.90	75.6	5.0	0.85	1.22	7.35	9
	4–6	Oh	3.90	2.90	86.4	2.1	0.64	0.99	4.02	4
	6–40	BbrA	4.30	3.70	6.7	0.1	0.04	0.05	0.24	3
	40–90	BbrC	4.60	4.00	3.2	0.1	0.04	0.04	0.25	7
	90–150	C	4.50	3.90	4.5	0.1	0.05	0.06	0.30	6
BŚl1	0–20	A	5.31	4.09	5.7	3.0	0.46	0.62	4.06	42
	20–40	Bbr	4.75	3.77	8.9	0.7	0.21	0.18	1.10	11
	40–85	Cgg	4.95	3.82	5.7	1.4	0.19	0.28	1.87	25
	85–120	Gor	5.68	4.19	2.1	2.6	0.16	0.39	3.21	60
BŚl2	0–24	A	6.14	5.18	4.2	7.9	0.28	1.61	9.84	70
	24–50	AC	6.47	5.37	2.7	6.8	0.11	0.75	7.82	74
	50–80	Cgg	6.60	5.32	3.0	6.8	0.12	0.79	7.88	72
	80–110	CG	6.60	5.20	3.1	7.5	0.16	0.94	8.72	74
BŚl3	1–5	A	5.20	4.20	15.8	8.3	0.45	1.67	10.41	40
	5–10	CA	5.60	4.50	2.6	3.1	0.17	0.61	3.94	60
	10–60	IIC	6.00	4.90	1.7	3.8	0.16	0.62	4.65	73
	60–150	IIIC	6.10	5.10	1.3	4.1	0.16	0.79	5.05	80
Pog.Śl	0–33	A	6.00	5.50	3.8	16.0	0.15	1.88	18.05	83
	33–61	ABbr	7.50	7.10	0.7	18.4	0.09	0.43	18.95	96
	61–77	BbrC	7.60	7.10	0.5	20.7	0.10	0.38	21.17	98
	77–130	C	7.30	6.60	0.6	13.8	0.11	0.16	14.14	96

Hh – hydrolytic acidity (cmol kg^{-1}); Ca, K, Mg, Na content (cmol kg^{-1}); S – sum of base cations (cmol kg^{-1})

(Table 4). The N^2/C parameter is within a wide range (0.006–0.040), with the lowest values in the Izerskie Mountains alluvial soil, the highest in the MDi from Beskid Śląski (BŚl3). Table 4 also shows the result of the total Corg stock (SOCS) calculation in the tested alluvial soils profiles. It ranges from 28.4 t ha^{-1} in the case of MDi (BŚl3) to 234 t ha^{-1} in the case of MDp of Babiogórski PN (BgPN2). On average SOCS in the analyzed soils it is 114.2 t ha^{-1}.

The SIGg value for the analyzed alluvial soils is from 20 to 38. The highest value was obtained for alluvial soil in Pogórze Śląskie, and the lowest SIGg values (<30) were calculated for alluvial soils formed in the complexes of granite rocks of the Izerskie Mountains and granitogneisses of the Tatra Mountains (TPN). In the second case, the location (above sea level) of the tested alluvial soil (1030 m above sea level) was decisive for the final value of the index. The performed PCA analysis confirmed the importance of the position in the height gradient in shaping soil properties (Fig. 3). MDbr are characterized by the highest acidification (Z_Y) and the worst properties of humus horizons expressed by the N^2/C ratio (Fig. 3).

The predominance of the riparian forest habitat was diagnosed on the plots. Forest habitats included in study were in their natural state without distortions. In three cases, distortion or degradation was reported as a result of human-induced dehydration (Table 5).

Table 4
Trophic Soil Index (SIGg) calculated for the tested alluvial soils and carbon stock

Profile	Zczs	Z_S	Z_Y	Yp	N^2/C	Altitude a.s.l.	Climatic factors	SOCS	SIGg
BgPN1	292.2	129.7	42.9	0.147	0.026	724	0.90	128.6	32.3
BgPN2	493.6	173.6	31.8	0.064	0.018	730	0.89	234.0	32.1
BgPN3	229.2	122.3	36.5	0.159	0.026	694	0.94	101.7	32.8
BsPN	387.5	104.2	57.1	0.147	0.036	675	0.96	139.8	34.7
TPN	323.6	61.7	23.7	0.073	0.025	1030	0.63	101.5	23.3
G.Izer.	116.2	4.0	70.2	0.604	0.006	475	1.00	70.1	20.0
BŚl1	135.8	31.1	77.4	0.570	0.012	530	1.00	68.1	30.0
BŚl2	360.6	110.8	41.8	0.116	0.013	570	1.00	114.6	35.0
BŚl3	130.5	66.5	26.8	0.205	0.040	520	1.00	28.4	34.0
Pog.Śl	593.2	229.9	20.1	0.034	0.029	360	1.00	155.3	38.0

Zczs – Stock of fraction < 0.02 (kg m^{-3}); Z_S – stock of the sum of basic exchangeable cations (mol m^{-3}); Z_Y – stock of acid ions (mol m^{-3}); Yp – converted acidity – the amount of acid ions per kg of fraction <0.02 in the soil pedon with a thickness of m^3; N^2/C – organic matter quality parameter in the first humus accumulation mineral horizon; SOCS – organic carbon in a soil column with a cross-section of 1 m^2 and a depth of 100 cm (t ha^{-1})

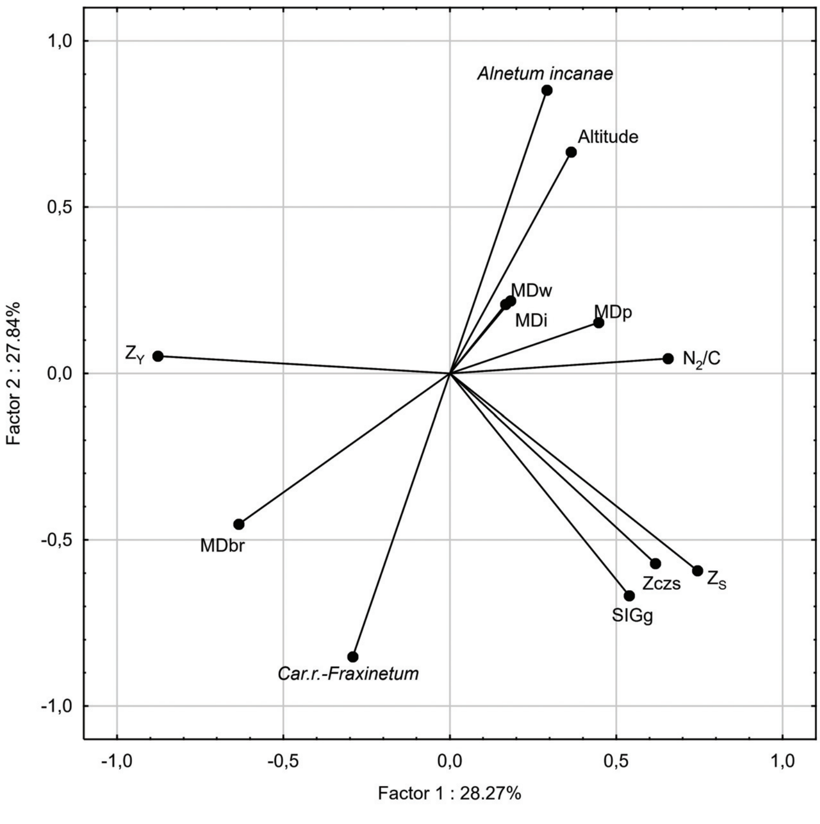

Fig. 3. The projection of variables on a plane of the first and second PCA factor; Zczs – Stock of fraction < 0.02 (kg m^{-3}); Z_S – stock of the sum of basic exchangeable cations (mol m^{-3}); Z_Y – stock of acid ions (mol m^{-3}); N^2/C – organic matter quality parameter in the first humus accumulation mineral horizon; MDi – Coarsic Leptosols (Fluvic), MDw – Fluvisols, MDp – Phaeozems (Fluvic), MDbr – Cambisols (Fluvic)

Table 5
Forest habitat type and its condition

Profile	Soil type	Bonitation class	Type of forest site	Distortion degree
BgPN1	MDp	I	LłG	N1
BgPN2	MDp	I	LłG	N1
BgPN3	MDw	I/II	LłG	N1
BsPN	MDbr	III	LłG	N1
TPN	MDw	II	LłG	N1
G.Izer.	MDbr	II	LłG	D
BŚl1	MDbr	II	LłG	Z1d
BŚl2	MDw	I	LłG	N2
BŚl3	MDi	III	LłG	N1
Pog.Śl	MDbr	II	Lwyż ł	Z1d

LłG – mountain riparian forest, Lwyż ł – upland riparian forest, N1 – natural state of forest site, D – degraded forest site, Z1d – forest site distorted by drainage, N2 – forest site close to natural state;

The analysis of the vegetation covering the discussed alluvial soils of the mountain area indicates the presence of two potential plant communities associated with these soils. These are *Alnetum incanae* communities and, in lower elevations, *Carici remotae-Fraxinetum* communities. The potential *Alnetum incanae* plant communities was established in seven plots, out of which six plots were characterized by the current vegetation consistent with the floristic characteristics of the communities. In the patches of a well-developed riverside alder complex, the stand consists of gray alder with numerous admixtures (*Frxinus excelsior, Picea abies, Abies alba, Acer pseudoplatanus, Salix fragilis*), while the lush undergrowth consists of numerous species usually dominated by *Petasites, Chaerophyllum hirsutum, Senecio fuchsii, Urtica dioica* and *Geranium robertianum* (Table 6). In one plot (G.Izer.), a strong distortion of the vegetation was found, the stand was dominated by spruce with an admixture of beech, and the species composition of the undergrowth vegetation did not include species characteristic of the *Alnetum incanae* communities, which may indicate a strong deformation of the habitat due to drainage and the absence of flooding conditioning the richness of vegetation. Potential vegetation of *Carici remotae-*

Table 6
Vegetation features accompanying the analyzed fluvisols

Study plot	Tree species composition	Potential plant association	The dominant plants of the undergrowth
BgPN1	9 gray alder, 1 fir, singly ash	*Alnetum incanae*	*Petasites hybridus* 4, *Chaerophyllum hirsutum* 2, *Senecio fuchsii* 2, *Petasites albus* 1, *Mercurialis perennis* 1, *Impatiens noli-tangere* 1, *Aegopodium podagraria 1*, *Tusilago farfara* 1, *Geranium robertianum* 1, *Cardamine flexuosa* 1, *Plagiomnium undulatum* 1
BgPN2	10 gray alder, singly ash, willow	*Alnetum incanae*	*Petasites hybridus* 3, *Petasites kablikianus* 2, *Chaerophyllum hirsutum* 1, *Senecio fuchsii* 2, *Petasites albus* 1, *Aruncus sylvestris* 1, *Stachys sylvatica* 1, *Aegopodium podagraria 1*, *Tusilago farfara* 1, *Geranium robertianum* 1, *Poa nemoralis* 1,
BgPN3	9 gray alder, 1 ash, singly sycamore, spruce	*Alnetum incanae*	*Petasites kablikianus* 3, *Petasites hybridus* 2, *Senecio fuchsii* 2, *Aegopodium podagraria 1*, *Aruncus sylvestris* 1, *Chaerophyllum hirsutum* 1, *Tusilago farfara* 1, *Geranium robertianum* 1, *Carduus personata* 1, *Plagiomnium undulatum* 1
BsPN	10 gray alder	*Alnetum incanae*	*Allium urisnums* 3, *Lunaria rediviva* 3, *Leucoyum vernum* 2, *Glechoma chirsuta* 2, *Stellaria nemorum* 2, *Symphytum cordatum* 1, *Dryopteris filix-mas* 1, *Chrysosplenium alternifolium* 1, *Asarum europaeum* 1
TPN	8gray alder, 2 spruce	*Alnetum incanae*	*Petasites kablikianus* 4, *Senecio nemorensis* 2, *Chaerophyllum hirsutum* 2, *Aegopodium podagraria* 2, *Stellaria nemorum* 1, *Urtica dioica* 1, *Rubus idaeus* 1, *Tusilago farfara* 1, *Geranium robertianum* 1, *Agropyron caninum* 1, *Stachys sylvatica* 1, *Poa nemoralis* 1, *Brachypodium sylvaticum* 1, *Festuca gigantea* 1, *Aconitum variegatum* 1
G.Izer.	9 spruce, 1 beech, singly gray alder	*Alnetum incanae*	*Deschampsia caespitosa* 2, *Calamagrostis arundinacea* 2, *Melampyrum pratense* 2, *Maianthemum bifolium* 2, *Prenathes purpurea* 1,
BŚl1	6 sycamore, 1ash, 1spruce, 1 aspen	*Carici remotae-Fraxinetum*	*Petasites albus* 3, *Aegopodium podagraria* 2, *Urtica dioica* 2, *Mercurialis perennis 1*, *Chaerophyllum hirsutum* 1, *Brachypodium sylvaticum* 1, *Athyrium filix-femina* 1
BŚl2	10 sycamore	*Carici remotae-Fraxinetum*	*Chaerophyllum hirsutum* 2, *Aegopodium podagraria* 2, *Petasites hybridus* 1, *Chaerophyllum aromaticum* 1, *Urtica dioica* 1, *Rubus idaeus* 1, *Senecio fuchsii* 1, *Impatiens noli-tangere* 1, *Geum urbanum* 1, *Plagiomnium undulatum* 1,
BŚl3	10 gray alder, singly ash, spruce, rowan	*Alnetum incanae*	*Petasites hybridus* 4, *Chrysosplenium alternifolium* 2, *Aruncus sylvestris* 1, *Primula elatior* 1, *Orchis fuchsii* 1,
Pog.Śl	10 ash, singly lime, sycamore, oak	*Carici remotae-Fraxinetum*	*Ficaria verna* 4, *Lamium maculatum* 3, *Anthriscus nitida* 1, *Symphytum tuberosum* 1, *Pulmonaria obscura* 1

degree of vegetation *cover* according to the *Braun-Blanquet scale*

Fraxinetum communities was assigned to three examined plots (BŚl1, BŚl2 and Pog.Śl), but only in the case of the last of them the current stand showed features typical for this complex (ash dominance). In the remaining two, the undergrowth vegetation typical of riparian habitats was present, but sycamore dominance was found in the stand (Table 6). PCA analysis confirmed the relationship between *Carici remotae-Fraxinetum* communities with lower positions in the height gradient and with MDbr (Fig. 3).

4. Discussion

In the presented set of plots, a strong relationship between the properties of the analyzed alluvial soils and the complexes of the formations in which alluvial deposits were formed was revealed. In mountain areas formed of acidic silicate rocks (granites, granite-gneiss, and Istebna sandstones), slightly poorer alluvial soils are formed, characterized by coarser graining and higher acidity. On the other hand, the complexes of richer deposits (Magura and Krosno sandstones, and especially sedimentary rocks containing calcium carbonate), create conditions for the formation of richer alluvial soils (with finer graining and higher abundance in alkaline cations). In the analyzed set, there were areas under protection (from the BgPN, BsPN and TPN areas) and areas from managed forests. In the second group of plots, the cambic process occurred more often within the analyzed soils, which may be associated with some signs of transformation of these areas caused by the regulation of water conditions and a change in the natural flooding regime for the riparian areas. Ecosystems of mountain riparian forests are one of the areas exposed to the processes of distortion and even degradation (Pielech et al., 2017; Alipić et al., 2022; Rodríquez-González et al., 2022). In forest sites studies, the presence of the cambic process in the alluvial soils profile is treated as a symptom of their distortion, proving the transformation of water conditions and the cessation of regular flooding (CILP 2012; Lasota and Błońska, 2013). The weathering processes accompanying the cambic processes take place in highly aerated higher terraces lying below the humus horizon, which were beyond the reach of the river floodplains as a result of natural processes of deepening the river bed, or more often as a result of man-made regulation of the watercourse bed. The formation of the cambic horizon is a natural consequence of the drainage of alluvial soils (Chojnicki, 2002; Kawałko et al., 2021). This process occurs faster in soils containing a higher proportion of the clay fraction, and in the case of sandy soils, it requires a longer time. The weathering process taking place in the surface horizons of river wastes usually leads to their depletion. In the analyzed set of plots, in the case of three cases of MDbr prepared from acidic deposits without carbonates, superficial acidification of these soils was observed, including the humus accumulation horizon and the cambic horizon. Only in the case of one plot, where the alluvial sediments contained calcium carbonate, the cambic process was not accompanied by acidification of the soil surface horizons. The consequence of the drainage processes of floodplains is the inhibition of the processes of accumulation of organic matter and the transformation of humus horizons towards the umbric horizons (Łabaz and Kabała, 2014, 2016).

It is difficult to unambiguously connect the analyzed alluvial soils of the mountain area with potential plant communities. Two communities were found in the analyzed group of plots – *Alnetum incanae* and *Carici remotae-Fraxinetum*. In floristic studies, their occurrence is rather different in terms of location conditions. *Carici remotae-Fraxinetum* in its submontane form is usually found lower on the border of the foothills zone and the lower mountain range, although there are known locations in the uplands of southern Poland. *Alnetum incanae* is a typical mountain complex occurring in the lower montane region (Matuszkiewicz, 2001). The analysis and field observations show that the above-mentioned forest complexes may occur in close proximity, while *Alnetum incanae* may occupy less stable, younger terraces with poorly developed soils. *Carici remotae-Fraxinetum* communities require more stable, well-developed soils, usually on higher, less flooded terraces, where the alluvial soils are deeper, often with a cambic process (Lasota and Błońska, 2013). In addition, *Carici remotae-Fraxinetum* covers a wider amplitude of soil conditions, occupying wet or floating areas, valleys with Gleysols, deluvial soils, Mollic gleysols and Mollic cambisols (Matuszkiewicz, 2001; Pawlaczyk, 2004). In the analyzed collection, *Alnetum incanae* was found on all alluvial soils, *Carici remotae-Fraxinetum* occupied MDbr and MDw was found at the transition between foothills and lower montane, which coincides with the range of its submontane form (Wilczek, 1995; Wilczek and Cabała, 1989). In the case of *Carici remotae-Fraxinetum* ecosystems, the problem of ash dieback caused by the fungus *Chalara fraxinea* has been present since the beginning of the 1990s (Kowalski and Łukomska, 2005; Kowalski, 2007). This problem concerns both managed forests and protected areas. In the original ash stands, there is a gradual change in the species composition of the stands, during which the sycamore maple is the species replacing the common ash in the discussed habitats, with the participation of black alder and gray alder. In the case of two analyzed plots from the area of the Silesian Beskids (BŚl1, BŚl2), the described phenomenon occurred.

In the typological forest sites classification, the presented plots were included in the habitats of the mountain riparian forest (LŁG). As far as the condition of habitats is concerned, most of the analyzed plots should be considered as habitats in their natural state. In the case of the area of the Izerskie Mountains (G.Izer.), the habitat is strongly distorted (CILP, 2012). This is evidenced by the presence of a type of humus characteristic of poorer habitats, the complete absence of indicator plants for riparian habitats, as well as the presence of the cambic process in the soil along with a strong acidification of the soil. Such strong changes in soil features and vegetation are probably the result of river regulation and the long-term lack of flooding. The forest sites assessment using the SIGg index suggests the presence of mesoeutrophic or eutrophic forest sites (SIGg value 30–38) in most of the analyzed areas. Only two profiles have a low SIGg value. This applies to alluvial soil of the Izerskie Mountains (due to the very low supply of basic cations and strong acidification), and alluvial soil from the Tatra National Park area due to their high location. In the valorization with the use of SIG for mountain soils (Brożek et al., 2016) in relation to the position in the altitude gradient, a climatic correction is introduced.

5. Conclusions

- The properties of mountain alluvial soils are related to the properties of the rock complexes within which alluvial terraces are formed.
- Mountain alluvial soils depend on the anthropogenic factors.
- River regulation and the disappearance of floods result in the formation of soils with a cambic horizons and acidification of the surface horizons devoid of the influence of water. This phenomenon leads to the depletion of the species composition of phytocoenoses and the distortion of habitats.
- Two main plant communities are associated with mountain alluvial soils: *Alnetum incanae* and *Carici remotae-Fraxinetum.*
- Ecosystems related to mountain alluvial soils are very valuable due to their high biodiversity and fulfilling various ecosystem functions.

References

Alipić, F., Milovanović, J., Pielech, R., et al. 2022. The status and role of genetic diversity of trees for the conservation and management of riparian ecosystems: A European experts' perspective. Journal of Applied Ecology 59, 2476–2485. https://doi.org/10.1111/1365-2664.14247

Braun-Blanquet, J., 1932. Plant sociology: the study of plant communities. McGraw-Hill, New York, NY, US.

Brożek, S., Zwydak, M., 2003. Atlas of Polish Forest Soils. CILP. Warszawa: 467 pp. (in Polish)

Brożek, S., Lasota, J., Błońska, E., Wanic, T., Zwydak, M., 2015. Waloryzacja siedlisk obszarów górskich na podstawie siedliskowego indeksu glebowego (SIG). Sylwan 159(8), 684−692.

Brożek, S., Lasota, J., Błońska, E., Zwydak, M., Wanic, T., 2016. Siedliskowy indeks glebowy w diagnozie siedlisk górskich. [w:] Siedliska leśne zmienione i zniekształcone. Zielony R. [red.] CILP. Warszawa: 63–78

Chojnicki, J., 2002. Soil-forming processes in alluvial soils of the Middle Vistula River Valley and Żuławy. Fundacja Rozwój SGGW, Warszawa: 5–83 (in Polish).

CILP 2012. Instrukcja Urządzania Lasu. Część II. Instrukcja wyróżniania i kartowania w Lasach Państwowych typów siedliskowych lasu oraz zbiorowisk roślinnych. Centrum Informacyjne Lasów Państwowych, Warszawa. ISBN 978-83-61633-70-9.

Classification of Forest Soils in Poland. 2000. CILP Warszawa. (in Polish)

Coelho, C.O.A., Ferreira, A.J.D., Laouina, A., Hamza, A., Chaker, M., Naafa, R., Carvalho, T.M.M., 2004. Changes in land use and landmanagement practices affecting land degradation within forest andgrazing ecosystems in theWestern Mediterranean. In S. Schnabel & A. Ferreira (Eds.), Advances in GeoEcology 37: Sustainability of agrosilvopastoral systems–Dehesas, Montados (pp. 137–153). Reiskirchen, Germany: Catena Verlag.

Falkowski, E., 1971. History and development forecast for the layout of the bed of selected sections of lowland rivers in Poland. Geological Bulletin of the Faculty of Geology UW, t. 12. (in Polish)

IUSS Working Group WRB, 2022. World Reference Base for Soil Resources. International soil classification system for naming soils and creating legends for soil maps. 4th edition. International Union of Soil Sciences (IUSS), Vienna, Austria.

Kacprzak, A., Drewnik, M., Musielok, Ł., 2012. Properties and classification of soils developed on Holocene river deposits in upper San river valley near Tarnawa Wyżna. Roczniki Bieszczadzkie 20, 281–295.

Kawałko, D., Jezierski, P., Kabała, C., 2021. Morphology and Physicochemical Properties of Alluvial Soils in Riparian Forests after River Regulation. Forests. 12(3), 329.

Kobierski, M., Banach-Szott, M., 2022. Organic Matter in Riverbank Sediments and Fluvisols from the Flood Zones of Lower Vistula River. Agronomy 12(2), 536.

Kowalski, T., Łukomska, A., 2005. Badania nad zamieraniem jesionu (*Fraxinus excelsior* L.) w drzewostanach Nadleśnictwa Włoszczowa. Acta Agrobotanica 58, 429–440.

Kowalski, T., 2007. *Chalara fraxinea* – nowo opisany gatunek grzyba na zamierających jesionach w Polsce. Sylwan 4, 44–48.

Lasota, J., Błońska, E., 2013. Siedliskoznawstwo leśne na nizinach i wyżynach Polski. Wydawnictwo Uniwersytetu Rolniczego w Krakowie.

Łabaz, B., Kabała, C., 2014. Anthropogenic transformation of soils in the Barycz Valley–Conclusions for soil classification. Soil Science Annual 65, 103–110.

Łabaz, B., Kabała, C., 2016. Human-induced development of mollic and umbric horizons in drained and farmed swampy alluvial soils. Catena 139, 117–126.

Matuszkiewicz, J.M., 2001. Zespoły leśne Polski. Wyd. Nauk. PWN. Warszawa.

Ostrowska, A., Gawliński, S., Szczubiałka, Z., 1991. Metody analizy i oceny właściwości gleb i roślin (Methods of analysis and assessment of soil and plant properties). Environmental Protection Institute, Warszawa, 333 pp. (in Polish)

Pawlaczyk, P., 2004. Podgórski łęg jesionowy [w:] Poradniki ochrony siedlisk i gatunków Natura 2000 – podręcznik metodyczny. Tom 5. Lasy i bory. [red. Herbich J.], 227–232.

Pielech, R., Bodziarczyk, J., Gazda, A., Malicki, M., Szwagrzyk, J., 20017. Łęgi w źródliskach i przy drobnych ciekach wodnych; jak identyfikować, kartować i chronić te zbiorowiska? Studia i Materiały CEPL w Rogowie 51(2), 93–102.

Polish Soil Classification, 2019. Polskie Towarzystwo Gleboznawcze, Komisja Genezy Klasyfikacji i Kartografii Gleb. Wydawnictwo Uniwersytetu Przyrodniczego we Wrocławiu, Polskie Towarzystwo Gleboznawcze, Wrocław-Warszawa: 250 pp. (in Polish)

Rivera-Ferre, M.G., Lopez-Gelats, F., Howden, M., Smith, P., Morton, J.F., Herrero, M., 2016. Re-framing the climate changedebate in the livestock sector: Mitigation and adaptation options. Wiley Interdisciplinary Reviews: Climate Change 7, 869–892.

Rodrigo-Comino, J., Keshavarzi, A., Senciales-González, J.M., 2021. Evaluating soil quality status of fluvisols at the regional scale: A multidisciplinary approach crossing multiple variables. River Research and Applications 37, 1–15.

Rodríquez-González, P.M., Abraham, E., Aguiar, F., et al. 2022. Bringing the margin to the focus: 10 challenges for riparian vegetation science and management. WIREsWater 5, e1604.

Wanic, T., Brożek, S., Lasota, J., Zwydak, M., 2011. Soil diversity of the alder and riparian forest communities. Roczniki Gleboznawcze – Soil Science Annual 62, 109–123.

Wilczek, Z., 1995. Zespoły leśne Beskidu Śląskiego i zachodniej części Beskidu Żywieckiego na tle zbiorowisk leśnych Karpat Zachodnich. Prace Nauk. Uniwersytetu Śląskiego w Katowicach 1490, 5–130.

Wilczek, Z., Cabała, S., 1989. Zespoły leśne grupy Klimczoka w Beskidzie Śląskim. Cz. 2. Zespoły lasów liściastych. Acta Biologica Silesiana 12(29), 79–90.

Siedliska leśne wykształcone na madach rzecznych w terenie górskim

Słowa kluczowe

Ekosystem leśny
Szata roślina
Właściwości gleb
Siedliskowy Indeks Glebowy

Streszczenie

Celem badań było przedstawienie właściwości mad rzecznych występujących w górskich obszarach leśnych. Dodatkowo w pracy przedstawiono charakterystykę roślinności towarzyszącej badanym glebom. Szczegółowa charakterystyka przedstawiona w pracy obejmowała drzewostany oraz roślinność runa. Badaniami objęto 10 powierzchni badawczych reprezentujących tereny górskie. Powierzchnie badawcze znajdowały się w Nadleśnictwie Bielsk, Ustroń, Szklarska Poręba, Węgierska Górka oraz w Bieszczadzkim, Babiogórskim i Tatrzańskim Parku Narodowym. Na każdej powierzchni próbnej wykonano szczegółowy opis profilu glebowego, z każdego poziomu genetycznego pobrano próbki w celu wykonania podstawowych oznaczeń laboratoryjnych. Na każdej powierzchni badawczej wykonano zdjęcie fitosocjologiczne metodą Brauna-Blanqueta oraz opis drzewostanu. Rozpoznanie typu siedliskowego lasu określono zgodnie z Instrukcją Urządzania Lasu, a dodatkowo obliczono Siedliskowy Indeks Glebowy. Właściwości górskich mad rzecznych są związane z właściwościami skał, w obrębie których tworzą się terasy aluwialne. Analizowane mady rzeczne zostały zaklasyfikowane do kliku podtypów tj. inicjalne, właściwe, brunatne i próchniczne a ich właściwości zależą od położenia doliny i od czynników antropogenicznych. Regulacja rzek i zanik zalewów powodują kształtowanie się gleb z poziomem brunatnienia i zakwaszeniem poziomów powierzchniowych. Z górskimi madami rzecznymi związane są dwa zbiorowiska roślinne: Alnetum incanae i Carici remotae-Fraxinetum. Ekosystemy związane z górskimi madami rzecznymi są bardzo cenne ze względu na ich wysoką bioróżnorodność i pełnienie różnych funkcji ekosystemowych.