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Stream ecosystems in mountain grassland (West Carpathians)*

1. Introduction and description of the investigated area

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Abstract — The streams investigated: Biała Woda, Czarna Woda, and Kamionka drain two morphological units of the West Carpathians: in the north the Beskid Sądecki Mts, composed of the Carpathian flysch, and in the south the Małe Pieniny Mts, built up to Jurassic and Lower Cretaceous limestones. The areas is in the most part covered with brown acid soils and podzolic soils, with a smaller percentage of neutral or alkaline soils (rendzinas). The dominating form of land use in the catchment basin are forests and pastures utilized for sheep grazing. The investigations were carried out at stations in which the character of the catchment basin was the modifying agent.

Key words: stream ecosystems, influence of pastoral economy, the West Carpathians, geology, pedology, hydrography.

1. Research assumptions

The mountain areas are very important in the water balance of Poland. The only water reserve, stored up in winter and spring, capable of meeting water deficits in central Poland is to be found in the Carpathians, where the highest annual precipitation is contracted. The Carpathians (within the borders of Poland), although they cover only of 6% the country's area, supply as much as 13% of the total runoff from the territory of Poland (Dębski 1967). The waters of the Carpathian streams and

* The investigations were carried out within Project 10.2.

rivers are still relatively clean. Nevertheless, human economic activity in recent years has led to a continual lovering the water quality.

One of the reasons for this is the intensification of agricultural production by way of increased mineral fertilization. In mountain areas with sharp inclines precipitation causes soil erosion and the washing away of biogenous substances, resulting in the eutrophication of the water in streams and rivers. Therefore, it is generally considered that the most favourable type of agricultural land use for mountain areas at an altitude of 500—1000 m and with inclines of over 10° is, apart form silviculture, pastoral economy which does not require ploughing (K u r e k et al. 1978). The oldest traditions in these areas are maintained by sheep farming.

In the years 1976—1978 the Laboratory of Water Biology Polish Academy of Sciences, carried out, in order to assess the influence of pastoral land use on the ecosystems of mountain streams, complex hydrobiological studies in the catchment basin of the upper Grajcarek (the West Carpathians), which is now the largest centre of sheep grazing in the Polish part of the Carpathians. The aim of the investigations was to provide facts which would testify that a process of transformation of the biocenoses under the impact of human economic activity had began.

The scope of the studies included: chemical investigations performed by M. B o m b ó w n a in 1676 and K. P a s t e r n a k in 1977/78 (macroelements) and by M. R e c z y ń s k a - D u t k a (microelements) as well as bacteriological by A. S t a r z e c k a and K. T r e l a, algological by B. K a w e c k a and faunal ones together with microfauna by E. G r a b a c k a, *Oligochaeta* by E. D u m n i c k a, and the remaining faunal groups by A. K o w n a c k i. Ichthiological studies carried out in the area by J. S t a r m a c h were also utilized.

Cooperation was also arranged with the Institute for Lands Reclamation and Grassland Farming (IMUZ) in Cracow whose workers S. K u r e k and J. P a w l i k - D o b r o w o l s k i have prepared a hydrological paper, and with the Department of General Zoology of the University of Łódź whose worker S. N i e s i o ł o w s k i has elaborated materials of *Simuliidae* and *Empididae*.

2. Description of the study area

2.1. General characteristics of the upper Grajcarek catchment basin

The investigations were carried out in the upper Grajcarek catchment basin, in the region of the village Jaworki (the West Carpathians). This area, owing to many years' investigations by various scientific institu-

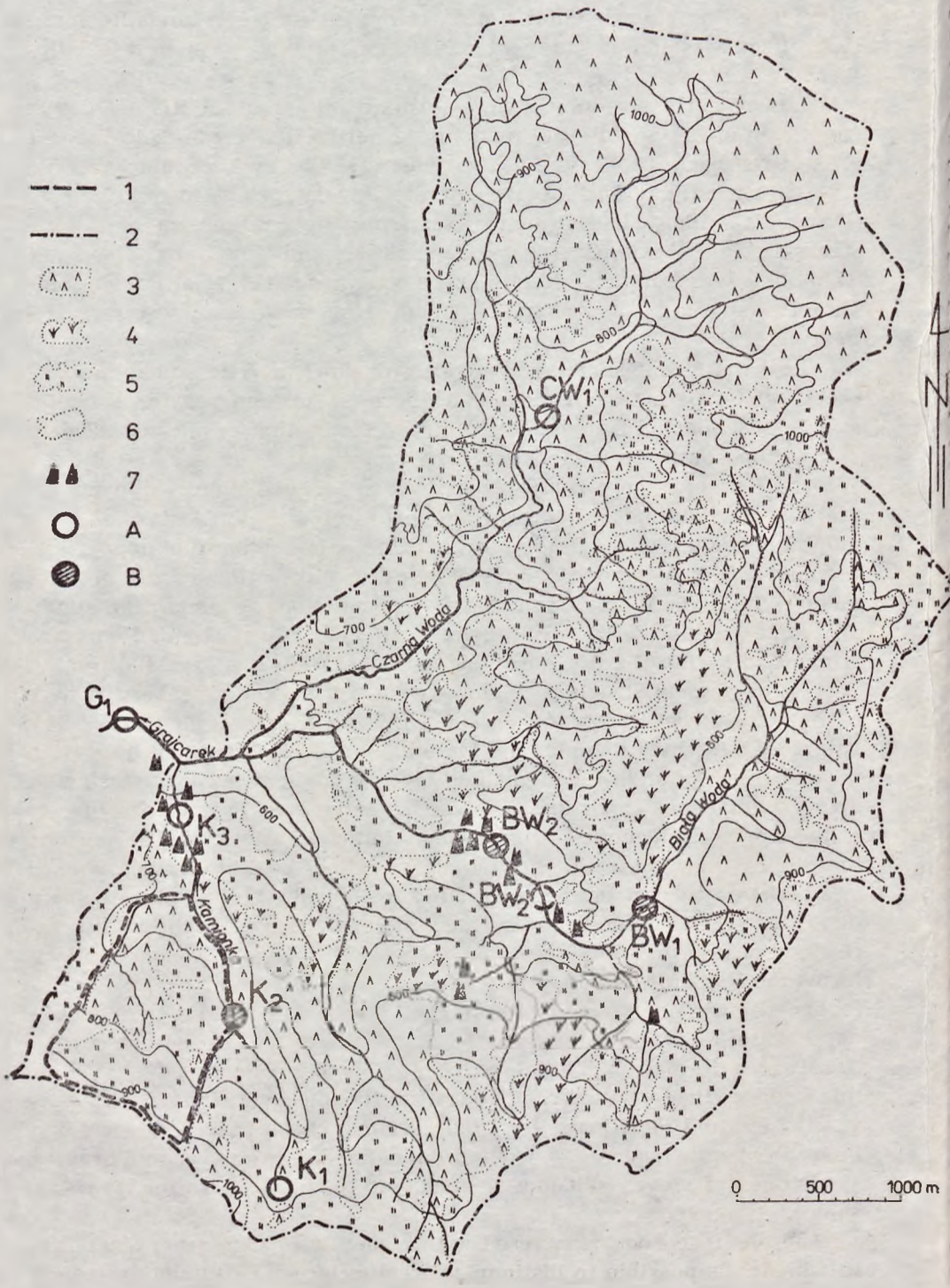
tions, based an experimental station of the Institute for Lands Reclamation and Grassland Farming at Jaworki, is among the best studied terrains in Poland.

The Grajcarek stream is a rigth—bank tributary of the River Dunajec (the basin of the Vistula draining to the Baltic). Its length is 15 km, the area of the basin 84.97 sq. km, the density of the hydrographic network 1.54 km per sq. km, and the average slope from springs to outlet 35.3% (Prochal 1962). The stream arises from the conjunction of several streams: Biała Woda, Czarna Woda, Skalski, and Kamionka. The name Kamionka was adopted after Birkenmayer (1971) although some authors use the names Homole stream, Homolski, Kaniowski, or Koniowski.

The head streams of the Grajcarek drain 2 morphological units of the West Carpathians. In the north, there is the high parallel range of Radziejowa (Beskid Sądecki Mts) with a culmination at altitude 1265 m, and in the south the Małe Pieniny range which culminates at altitude 1050 m. Between these ranges there is a subsequent depression out by the Brysztan stream and the lower reach of the Biała Woda. Both mountain ranges, gently falling towards the axis of a parallel depression, are cut by deep V-shaped valleys of meridional direction, whose bottoms include the Biała Woda (upper each), Czarna Woda (draining the southern slopes of the Radziejowa range), and the Skalski and Kamionka streams (draining the northern slopes of the Małe Pieniny Mts) (fig. 1).

The geological structure of the area is very complex. There is here a contact between the Magura nappe and the Klippen Belt (fig. 2). The Klippen Belt, which includes the Małe Pieniny Mts, is marked by a wide variety of rocks and by complicated tectonics. There occur Jurassic and Lower Cretaceous limestones as well as sandstones, shales, and marls of the Upper Cretaceous and Paleogene Jurassic and Lower Cretaceaous limestones underwent threefold foldings. Limestone blocks, very hard and resistant to destruction, embedded in less resistant sandstone-shaly deposits, were exposed to the surface and now form differentiated picturesque rock forms and limestone gorges. The Magura nappe which forms the Radziejowa range is a younger element formed after the Paleogene and is composed of the Carpathian flysch. Within the Magura nappe 2 series of deposits may be distinguished. The lower one, called Szczawnica formation, of Paleocene and Eocene age is developed as thin-bedded, fime-grained sandstones interbedded with limy shales heavily folded and densly cut by calcite veins: The higher one, including beds of Magura sandstone, composed of medium and coarse-grained sandstones of clayey-siliceous cement, interbedded with thin layers of shales.

The older bedrock is covered with a mentle of Quaternary deposits in which it is possible to distinguish weathering and solifluction covers



and fluvial deposits. The fluvial deposits include sandy-clayey gravels and alluvial clays to be found in the bottoms of major valleys. They compose 3 terraces which have been preserved in fragments and run along both sides of the bed of the Biała Woda and Czarna Woda (Gerlach 1966, Birkenmayer 1970, 1979).

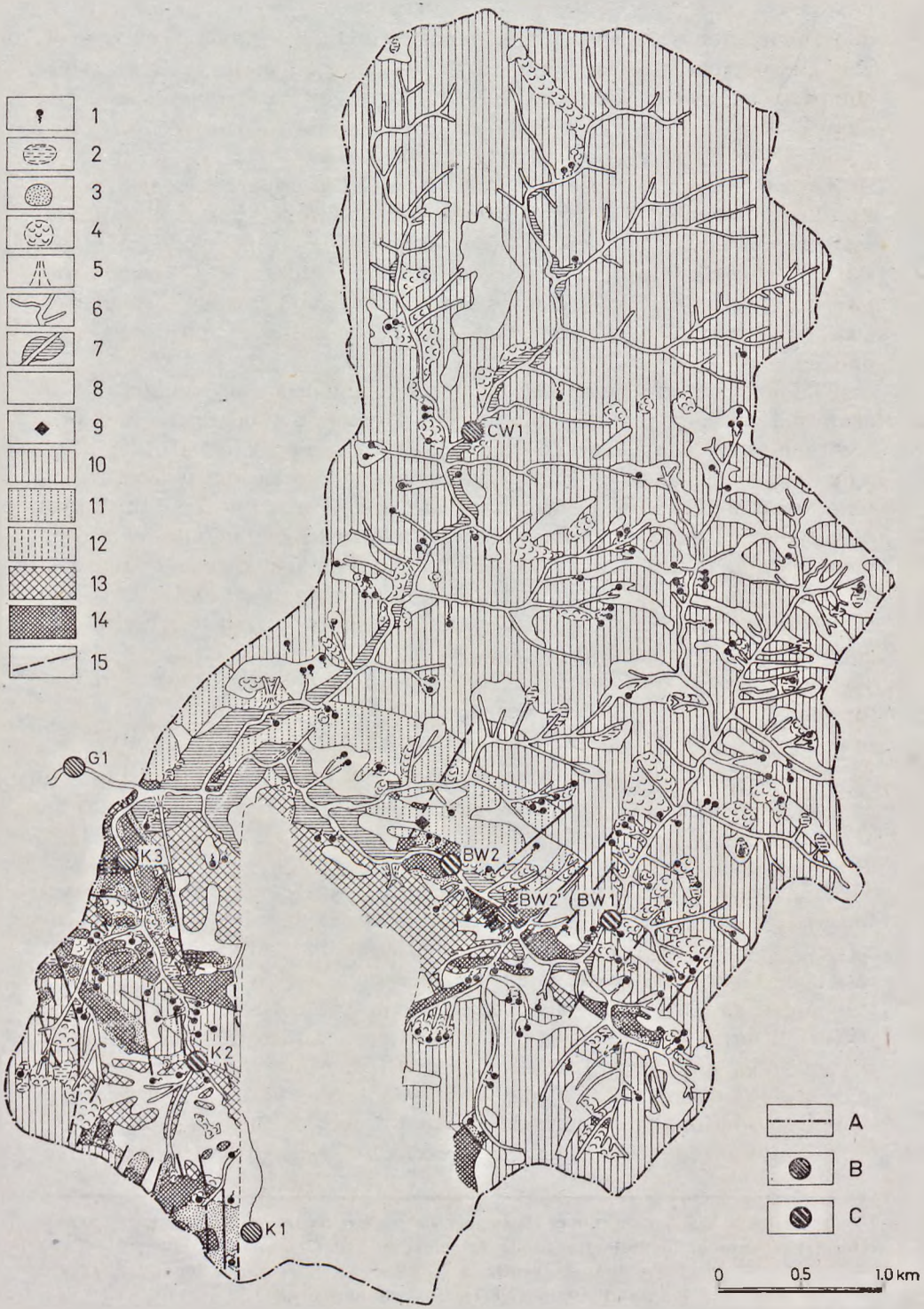
The soil cover in the catchment basin of the upper Grajcarek is generally represented by clayey brown and podzsolic soils while alluvial soils, rendzinas, boggy, and skeleton soils cover an inconsiderable area (fig. 3). These are predominantly acid soils which were derived from flysch deposits (acid brown soils and podzolic soils), with a small percentage of neutral or alkaline soils formed on Jurassic limestones (rendzinas).

The soils within the investigated catchment basin are vulnerable to erosional processes, whose intensity is limited by the forest and pastural land use (Komornicki 1958, Dobrzański et al. 1958, Dobrzański et al. 1962). The perviousness of brown and podzolic soils varies and depends on the way they are used. On arable land the speed of percolation is 35 mm/min., in forests it falls to 2.5 mm/min., while on pastures it is reduced to as little as 0.7 mm/min. This great decrease in the speed of percolation on pastures results among other factors from the treading down of the soil by cattle and sheep, owing to which it becomes more compact and loses its primary texture (Gerlach 1966). The possibility of surface run-off on slopes under pasture thus increases considerably.

2.2. Management of the upper Grajcarek catchment basin

Till World War II the area under study was densly populated and intensively used agriculturally. The main stress was laid on land cultivation, vegetable growing, and animal breeding. Silviculture was of auxiliary character. Apart from the felling of timber from the forests they were also treatedas pasture for sheep and cattle and as a source of leaf litter. After the war the populations of the villages Jaworski, Biała Woda, and Szlachtowa were resettled. Most of the arable land was in 1947 given to the Podhale Union of Shepherds as pasture in compensation for the withdrawal of sheep from the Tatra National Park. In 1978 these lands were handed over to the Agricultural Cooperative

Fig. 1. Land use map of the upper Grajcarek catchment basin. 1 — boundary of experimental pasture of Institute for Lands Reclamation and Grassland Farming, 2 — watershed, 3 — forest, 4 — juniper bushes, 5 — meadows, 6 — arable land, 7 — rocks, A — stations in 1976/77, B — stations in 1977/78



Association (SKR) at Krościenko-Szczawnica. At present forests and pastures cover the greater part of the upper Grajcarek catchment basin. (In 1966 arable land lying around the village Jaworski constituted as little as 3% of the total area). Compact forest complexes occur in the upper reach of the Czarna Woda and of the Biała Woda, on the slopes of Radziejowa. Only in its top portions are there large areas of pasture in which rise the springs of the Biała Woda. In the region of the Skalski and Kamionka stream pastures are to be found on the slopes of deep valley incisions. The dominating species in the forests is spruce with an admixture of beech and fir (Fabjanowski 1962, Myczkowski, Grabowski 1962). Meadows and pastures occur on watersheds and on the mountain slopes. On grazing lands of Jaworki the following associations of pasture plants were distinguished: association of perennial ryegrass with crested dog's-tail *(Lolio-Cynosuretum)* which covers 35% of the pastures, association of gladiolus with common bent *(Gladiolo-Agrostetum)* 30% of pastures, association of moor mat-grass *(Hieracio-Nardetum)* 25%, association of tall cat grass *(Arrhenatheretum eltiorum)* 5%, and association of valerian with yellow sedge *(Valeriano-Caricetum flave)* 5% (Kostuch 1966, Kostuch, Król 1966, Jagła et al. 1977).

16 grazing areas (so-called cercles) were distinguished in the catchment basin of the upper Grajcarek (Table I). Besides, some nature reserves were also established. Of these the best, known is the Jan Wiktor Homole Gorge Reserve created in 1963, with an area of 58.64 ha, including the whole Homole gorge. The remaining reserves are Wysokie Skałki (High Rocks) above the Homole Gorge (10.9 ha), „Skalskie-Bednarówka" in the valley of the Skalski stream (19.0 ha), „Biała Woda" in the gorge of the Biała Woda which includes a group of limestone rocks forming a picturesque gorge (33.7 ha), and a forest reserve called „Nad Kotelniczym Potokiem" (above the Kotelniczy stream), with an area of 26.5 ha.

Fig. 2. Geological map with Quaternary cover of the upper Grajcarek catchment basin (after Birkenmajer 1957a, 1957b, 1970, 1971, simplified by M. Niemirowski). I — Quaternary cover: 1 — springs, 2 — bog-springs, 3 — talus cones, 4 — landslides, 5 — alluvial cones, 6 — valley alluvia, 7 — gravely-sandy terraces (Holocene and Pleistocene), 8 — weathering and solifluction clays. II — Miocene: 9 — basalt dyke, III — Paleogene and Cretaceous of the Magura nappe, 10 — Szczawnica formation — sandstones and shales (Paleocene and Lower Eocene) and Magura sandstones (Lower Eocene), 11 — Jarmuta formation mainly sandstones (Maastrichtian), 12 — Malinowa shale formation (Cenomanian-Campanian). IV — Jurassic and Cretaceous of the Klippen Belt and Jurassic of the Magura nappe, 13 — marls and shaly-sandstone deposits (Upper and Lower Cretaceous), 14 — limestones and cherts (Lower Cretaceous Upper and Middle Jurassic), marly shales and shaly sandstone deposits (Middle and Lower Jurassic). V — Tectonics: 15 — faults, A — watersheds, B — stations in 1976/77, C — stations in 1977/78

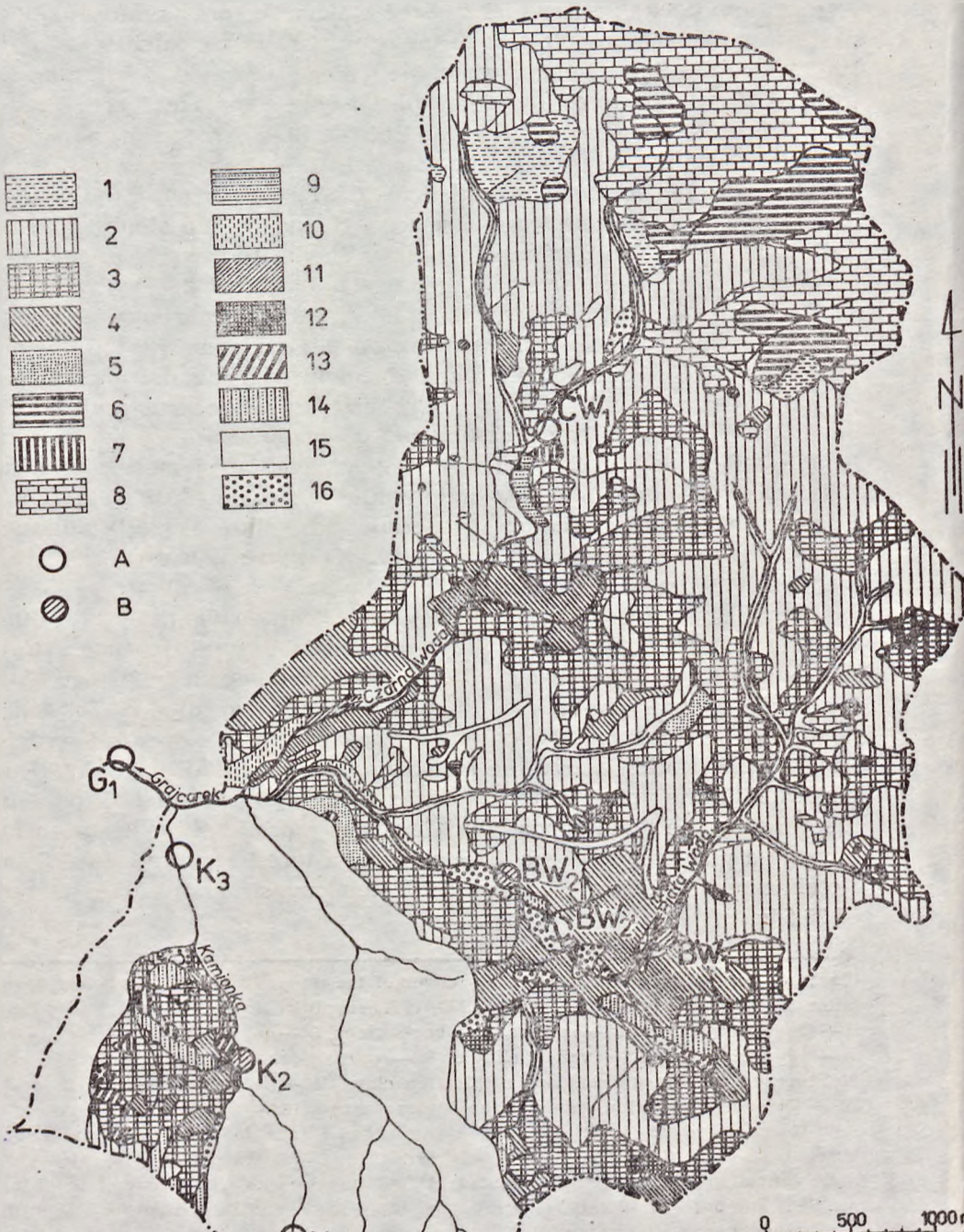


Table I. Area and stock of sheep on grazing areas at Jaworki in 1973 and 1978. (1973 stock according to Jagła et al. 1977, 1978 according to data from Agricultural Cooperative Association at Krościenko). 1 - the area of grazing plot (cercle) XI had decreased, in brackets area of 1978 is given

Number of cercle	Area in ha	1973		1978	
		number of sheep	stock of sheep (head/ha)	number of sheep	stock of sheep (head/ha)
I	80	900	11.2	930	11.6
II	65	600	9.2	700	10.7
III	65	600	9.2	600	9.2
IV	75	850	11.3	840	11.2
V	70	550	7.8	720	10.28
VI	52	400	7.7	550	10.5
VII	50	400	8.0	400	8.0
VIII	75	1 000	13.3	930	12.4
IX	65	650	10.0	660	10.1
X	60	450	7.5	450	7.5
XI	78 (70)[1]	400	5.1	450	6.0
XII	65	450	6.9	450	6.9
XIII	70	550	7.8	600	8.5
XIV	70	700	10.0	850	12.1
XV	50	450	9.0	500	10.0
XVI - IMUZ	53	—	—	650	12.6
Σ	1043 (1035)[1]	8 950	9.0	10 280	9.6

Until 1978 sheep grazing was carried on in the traditional manner, with 9 sheep on average per one hactare of pasture, although cercles with only 6 sheep per hectare could also be found (Table I). Inconsiderable also was the quantity of fertilizers spread, i.e. 37.8 kg of potassium, 48 kg of phosphorus, and 80.8 kg of nitrate per hectare (data for 1973 after Jagła et al. 1977). These figures, given by the Sheep Farmers Association at Nowy Targ, should, however, be treated with some scepticism, the amounts probably being smaller. Since 1978, when the pastures were taken over by the Agricultural Cooperative Association at Krościenko the quantity of fertilizers has increased. However, this does not concern the period of the described investigations. At the same time, on an experimental plot (cercle) of IMUZ, a larger stock of sheep were grazed and higher doses of artificial fertilizers applied. In the

Fig. 3. Soil map of the upper Grajcarek catchment basin (according to Dobrzański, Gliński, Guz 1962, Komornicki 1958). I — Brown soils: 1 — sandy, 2 — light loamy, 3 — medium loamy, 4 — heavy loamy, 5 — clayey. II — Podzolic soils: 6 — sandy, 7 — light loamy, 8 — medium loamy. III — Black earths: 9 — sandy, 10 — light loamy, 11 — medium loamy. IV — Hydromorphic soils: 12 — gley soils (sandy, loamy, clayey), 13 — soils with ground water. V — Brown rendzina soils: 14 — formed on Jurassic rarely also on Tertiary limestones. VI — Soils of the first stage of evolution with undeveloped profile, 15 — skeleton soils formed on non-calcareous flysch rocks. VII — Rendzina soils of the first stage of evolution. A — stations in 1976/77, B — stations in 1977/78

period between the autumn of 1976 and spring 1978 the following mineral fertilization was applied: in the second decade of October 1976, 29 kg of P_2O_5 per ha was spread in the form of 18% of superphosphate and 27 kg of K_2O per ha in the form of 60% potassium salt; in the first decade of May 1977, 38 kg of nitrogen per ha in the form of ure- and ammonium nitrate (each 50%); in the second decade of April 1978, 34 kg of nitrogen per ha in the form of ammonium nitrate (data from the Research Station of IMUZ at Jaworki). The stock of sheep at that time was 12.5 head per ha. Grazing in 1977 began on 29 April and ended on 23 September; in 1978 the corresponding dates were 5 May and 5 October.

2.3. Description of the streams investigated

The Czarna Woda stream drains the southern slopes of the Radziejowa range. Its sources are at an altitude of 1100 m. The stream flows north to south across a dense forest. Then at an altitude of 660 m it leaves the forest and makes its way through the village of Czarna Woda. At 566.6 m it joins the Biała Woda stream. The total length of the stream is 6.9 km, the area of its catchment basin 11.6 sq. km and its fall in profile 76.6‰. The stream is joined by the left-bank tributaries Spod Radziejowej, Spod Rohacza, Pokrywisty, a stream from Jasielnik, and by the right-bank Kotelniczy stream. All the streams join the Czarna Woda in its upper and middle reaches. Its bed is covered with stones and a small quantity of gravel. There are frequent rocks and rock projections in the bed, which form steps sometimes reaching as much as 1.5 m in height. In the catchment basin of the Czarna Woda forest constitutes 62.72% shrubs and juniper bushes 1.32% meadows and pastures 30.87%, and arable land 3.35%. The remaining area is covered by bog springs, ravines, buildings, and roads (situation in 1962 according to P r o c h a l 1962).

The Biała Woda, which is considered by some authors to be the head-stream of the Grajcarek, originates from the joining of 2 streams — Rohacz and Obidza, which drain the southern slopes of Wielki Rohacz (altitude 1182 m). They take their source from numerous springs and seeps leaking out at an altitude of 900—950 m from an area of pastures or on the borders between forests and pastures. The waters of these springs join to create small streamlets, which then give rise to the Rohacz and Obidza streams. These streams flow from north to south, initially through pastures and then through forest. At an altitude of 780 m they come together to initiate the Biała Woda which flows to south-westwards through a large complex of forests, emerging at 690 m. It then rapidly turns north-westwards, cutting through a range of limestone rocks, which form the gorge of the Biała Woda, now a nature

reserve. After leaving the gorge it continues through meadows and fields and in the village Jaworki joins the Czarna Woda at an altitude of 566.6 m. The total length of the stream is 7.9 km, the area of its catchment basin 10.91 sq. km, and its fall in profile 63.6‰ Apart from a few small unnamed streamlets and numerous springs, the stream is joined by the major left-bank tributaries of Szczob, Rozdziela, Brysztan, and Repowa in the upper and middle reaches, and by the right-bank Palenica in its lower reach. The bed of the Biała Woda is covered with broken rock debris. In the upper reach the material is distinguished by a large diameter but small thickness of the layer, while in the middle and lower reaches the diameter is smaller and the thickness of the layer is greater. Not infrequently sections of the bed are incised in form rock. These are to be found in the region of the Biała Woda Gorge and along short sections in the upper reach of the stream. In the rocky bottom of the channel there are steps, waterfalls, and cascades. The highest waterfall in the region of the gorge can be observed on a tectonic fault in the Biała Woda ravine. In the catchment basin of the Biała Woda forest constitutes 17%, meadows and pastures 43%, and arable land only 2.6% (P r o c h a l 1962).

The Kamionka stream drains the northern slopes of the Małe Pieniny Mts and originates from small helocrenous springs situated below Wysokie Skałki at an altitude of 860—880 m. The waters of these streams join together and flow steeply down through the gorge, whose the banks are overgrown with beech-spruce forest. At an altitude of 740 m it flows into an area of pastures where it receives the waters of an unnamed left-bank tributary which drains the slopes of the IMUZ demonstration pasture. At 680 m it once again enters an deep gorge forested, which it follows until it reaches a landslide in the upper part of the Homole Gorge. Along this section the stream flows down among large limestones boulders. It then flows into the Homole gorge and follows a rocky bed covered in places with boulders and stones. It joins the Grajcarek at an altitude of 560 m. The total length of the stream is 3.4 km, the area of its catchment basin 3.2 sq. km, and the fall in profile 87.2‰. The Kamionka, apart from the previously described unnamed tributary in its upper reach, has one major left-bank tributary called Koniowski or Kaniowski. In the Kamionka catchment basin forest cover 13% of the area while the remainder consists of meadows and rocks.

2.4. Stations and dates of researches

Investigations were carried out at 7 stations situated in the Biała Woda, Czarna Woda, Kamionka, and Grajcarek streams in the years 1976/77. A detailed description of the stations is given in Table II.

Table II. Physiographic characteristic of stations in the investigated streams of the upper Grajcarek catchment basin (samples from station BW 2 were taken in the season 1976/77, from station BW 2 in the season 1977/78. (1)- width and depth of the stream and speed of the current were recorded at low water stages; (2)- the Biała Woda stream was accepted as the headwater stream of the Grajcarek and the Rohacz stream as that of the Biała Woda

Name of stream	Number of station	Altitude above sea level in metres	Width in metres (1)	Depth in metres (1)	Speed of the current in m/sec (1)	Stream slope in ‰	Distance from spring in metres (2)	Bottom	Character of banks and land use of the catchment basin
Czarna Woda	CW 1	690	3	0.1-0.15	0.68	111	2500	stones, 20 cm in diameter (sandstones)	coniferous forest (spruce)
Biała Woda	BW 1	690	3-4.5	0.1-0.2	0.35	50	3250	boulders, stones, more than 20 cm in diameter (sandstones)	outflow from the forest, grassy banks, single coniferous trees (spruce, juniper)
	BW 2	640	2.7	0.15-0.25	0.59	26.6	4250	boulders, stones, more than 20 cm in diameter (sandstones, limestones)	steep-grassy banks, single trees (willows), natural surroundings of the pasture
	BW 2	650	4-4.5	0.10-0.20	0.51	26.6	4000	stones more than 20 cm in diameter (sandstones limestones)	flat grassy banks, natural surroundings of the pasture
Kamionka	K 1	840	0.5-0.7	-	0.14	200	10-30	single stones, clay earth, rotting leaves	ravine overgrown with beeches headwaters, surroundinga pasture under fertilization
	K 2	690	3	0.10	0.42	57	1250	stones, 10 cm in diameter, gravel	flat grassy banks, left bank - pasture under fertilization (IMUZ), right bank - young wood
	K 3	580	1-2	0.25	0.4	25	2700	limestone boulders, stones, 20 cm in diameter	steep limestone walls covered by forest (Homole Gorge Reserve)
Grajcarek	G 1	540	5.3	0.30	0.55	26.6	7500	stones, pebbles	banks covered with alders and willows which shade the stream, surroundings - village of Jaworki, arable land

Samples were collected five times: on 6 May 1976 prior to sheep grazing, on 22 June and 28 July 1976 during sheep grazing, on 16 September 1976 after the sheep grazing season, and once more on 24 March 1977. As very many agents could affect the character of biocenoses at these stations (land use, geology, altitude, degree of stream shading, etc.) in the next annual cycle of 1977/78 the number of stations was limited to three so that the only agent of significance should be the character of agricultural land use of the catchment basin. The investigations were carried out at stations BW1 in the Biała Woda just below the outflow from a large forest complex (control station), BW2 in the Biała Woda within an area of traditional pasturing, K2 in the stream Kamionka in an area of IMUZ experimental pastures where for many years an intensive pastoral system had been carried out, this including the spreading of considerable amounts of artificial fertilizers. On account of a planned field experiment station BW2 was moved downstream by 250 m, in the 1977/78 season.

Samples from these station were collected on the following dates: April 21, May 24, July 11, August 21, October 3, November 3, and December 19 1977, and February 20 and April 4 1978. At station BW2 additional samples were taken on August 2 and October 19 1977. Ichthyological studies were carried out at other time.

Acknowledgments

In the name of the whole research team as well as his own, the author wishes cordially to thank the Director of the Cracow Branch of the Institute for Lands Reclamation and Grassland Farming, Professor Ryszard Kostuch, for making available the facilities of the laboratories of the Research Station at Jaworki. Thanks are also due to Docent Stanisław Kopeć and Dr Jacek Pawlik-Dobrowolski, of that Institute, for giving access to data on the management of the experimental pastures of the Institute and on the hydrography of the terrain as well as for many consultations, both during the investigations and in the course of preparation of the paper for publication.

Special thanks are also expressed to Professor Krzysztof Birkenmayer for making available and giving consent to the use of unpublished geological maps of the catchment basins of the Czarna Woda and the Biała Woda, as well as for numerous consultations and kind assistance in the course of compiling a comprehensive geological map of the upper Grajcarek.

Professor Tomasz Komornicki's assistance in drawing up the pedological part of the paper is also deeply appreciated.

Besides, the research team would like to thank the administrative staff of the National Provincial Establishment of Animal Insemination at Zabierzów for allowing them to use the premises of the Sheep Insemination Station at Biała Woda.

In these grateful acknowledgments not to be omitted are the workers of the Agricultural Cooperative Association at Krościenko who supplied relevant data concerning pastoral management in the region of Jaworki.

Lastly, thanks are due to the local farmers, especially Józef Krzyśko, who were of ready assistance in carrying out the field work.

3. Polish summary

Ekosystemy potokowe na terenach pastwisk górskich (Karpaty Zachodnie)

1. Wstęp i opis terenu badań

Celem kompleksowych badań hydrobiologicznych prowadzonych przez Zakład Biologii Wód PAN w dorzeczu górnego Grajcarka było określenie rozwoju biocenozy potokowej na obszarach górskich w warunkach wpływu gospodarki pasterskiej.

Grajcarek, prawobrzeżny dopływ Dunajca, powstaje z połączenia się kilku potoków: Białej Wody, Czarnej Wody, Skalskiego i Kamionki (ryc. 1). Potoki te odwadniają dwie jednostki morfologiczne: na północy pasmo Radziejowej leżące w Beskidzie Sądeckim i na południu pasmo Małych Pienin. Małe Pieniny są zbudowane z wapieni jurajskich i dolnokredowych oraz piaskowców, łupków i margli wieku górnokredowego paleogeńskiego, natomiast pasmo Radziejowej tworzy flisz karpacki (ryc. 2). Obszar ten w przeważającej części pokryty jest kwaśnymi glebami, które utworzyły się z utworów fliszowych (gleby brunatne kwaśne i bielicowe), w małym procencie glebami obojętnymi lub zasadowymi, które powstały na wapieniach jurajskich (rędziny) (ryc. 3).

Obecnie w zlewni górnego Grajcarka dominują lasy i pastwiska. Pola orne, usytuowane wokół wsi Jaworki, zajmują nieznaczny procent. Na tym terenie wydzielono 16 terenów wypasowych, tzw. cerkli (tabela I), na których wypasy prowadzone są systemem tradycyjnym. Na 1 ha przypadało średnio 9 owiec. Jedynie na cerklu wzorcowym IMUZ (nr 16) stosowano większe obsady owiec — 12 owiec/ha — i wysiewano duże dawki nawozów.

W latach 1976—1977 badania prowadzono na 7 stanowiskach usytuowanych w potokach: Biała Woda, Czarna Woda, Kamionka, Grajcarek (tabela II). W następnym sezonie (1977/78) badania prowadzono na stanowiskach BW1 w Białej Wodzie usytuowanym tuż poniżej dużego kompleksu leśnego — stanowisko kontrolne; BW2 w Białej Wodzie, na terenie pastwisk, gdzie wypasy prowadzono systemem tradycyjnym; K2 w potoku Kamionka, na obszarze pastwisk doświadczalnych IMUZ, gdzie od wielu lat prowadzono intensywną gospodarkę pasterską, wysiewając na łąki znaczne ilości nawozów sztucznych.

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