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GEOGRAPHICAL INDIVIDUALITY OF BASINS WITHOUT OUTLETS IN A POST-GLACIAL AREA (THE PARSĘTA CATCHMENT, WEST POMERANIAN PROVINCE)

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Abstract: The paper seeks to present the exceptional qualities of closed basins commonly found in areas covered by the last Pleistocene glaciation. Such basins are a natural part of the landscape; they occupy a large percentage of the area. The research was conducted in the Parsęta catchment over the course of several years. Two basic types of basins without outlets were analyzed: absorptive basins, evapotranspiration basins. The geographical individuality of small landforms with no surface runoff was characterized on the basis of key morphometric indicators, lithology, soil distribution, and physical-chemical properties of surface and groundwaters. Closed basins are usually small concave landforms, roughly circular in shape, at the bottom of which organic sediments attain a great thickness. In the southern part of the Parsęta catchment, permeable sediments predominate, while those located in its middle part are predominantly retentive in nature. Typical features of the spatial distribution of soils in the small catchments of closed depressions are their ring-like pattern going down towards the bottom and a predominance of organic soils in the bottom. Surface and groundwaters in these catchments display a low and a medium level of mineralization, and the elements dominating in their chemical composition are those coming from the leaching of rocks, the chief source of which is chemical weathering, as well as biogenic components connected with the deposition of organic sediments in the bottoms.

Keywords: post-glacial area, closed depression, morphometric indicators, lithology, soils, water chemistry

Introduction

The post-glacial area is characterised by a high diversity of terrain. In the heterogeneous system of post-glacial forms there are numerous melt-out depressions which are valuable objects for study. They play a major role in the operation of the present denudation system in the post-glacial area, constituting local denudative-accumulative lowest levels and affect the current performance of water circulation in the catchment. In order to get to know some individual elements of the geographical environment in details it is necessary to conduct comprehensive (geomorphological, palaeographical, hydrological and geoecological) studies supported by interdisciplinary work within the boundaries of this confined hydrological unit (the Parsęta catchment). The analysed depressions are a characteristic morphological element, particularly in the southern part of the catchment. The unique nature of these small landforms with no surface runoff refers to the diversity of morphometric indicators, lithology, soil distribution and physical-chemical properties of surface and groundwaters which are good indicative qualities of the present landscape changes and, when compared to other parameters, register environmental changes better.

Study area

The Pomeranian region is one of the clearly-outlined geomorphological units in the Polish Lowland. Its morphological axis is made by the so-called lakeland elevation. It falls northerly in a series of clear, morainic upland levels making a line of coastal lowlands. In the area Karczewski (1988) distinguished seven morainic upland levels which are separated by distinct morphological thresholds and are located within the specified height ranges and are characterised by their lithofacial variability showing regularity in the distribution of sediments which build individual levels. This morpholithological diversity of the post-glacial area is perfectly fitted into by the Parsęta catchment, one of the coastal rivers, within which all upland levels can be distinguished.

The Parsęta catchment (Fig. 1) covers an area of 3150.9 km^2 (Hydrological Division of Poland 1983; Stachy 1986), representing 1% of Poland's area. The length of the river in the mainstream is equal to 139.4 km and 117.2 km in the axis of the valley. Declines in the upper river course amount to 3‰, and the average decline in the mainstream is 0.98‰ (Choiński 1998).

In landscape terms, the Parsęta catchment is located in the temperate climatic zone, in the Central Polish Anticlinorium, the post-glacial area of the Pomeranian stadial, within the boundaries of Baltic and lake-district climates, in the region of coastal rivers with their ground-rain-snow supply, in the area of moist-zone

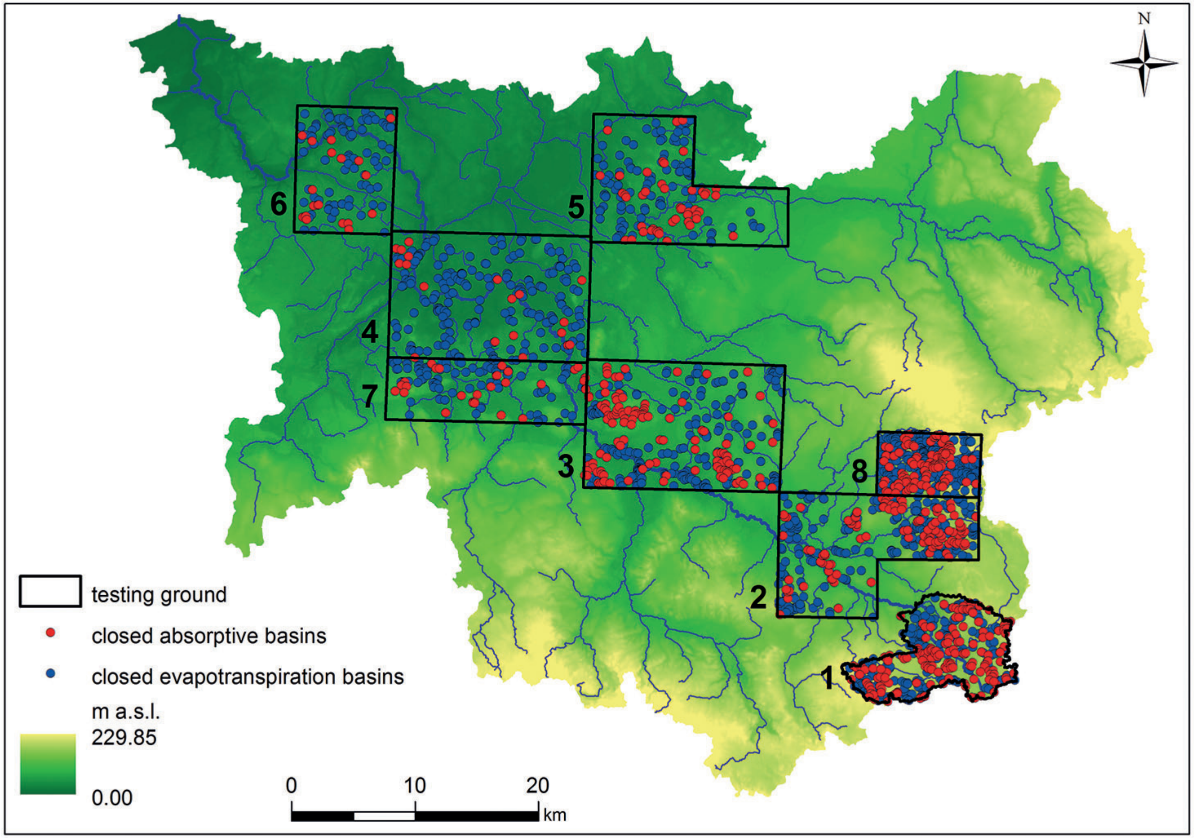

Fig. 1. Distribution of closed basins in the Parsęta catchment (in the research fields)

Source: author's own study.

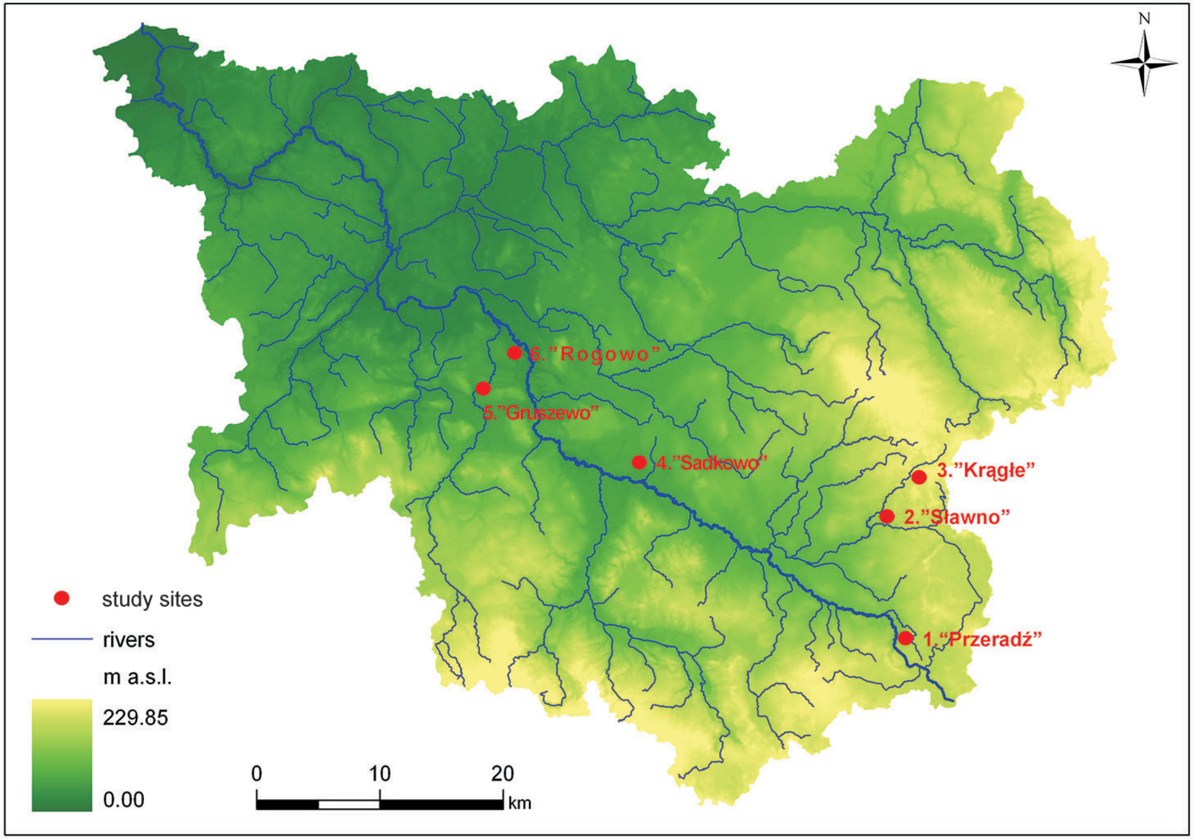

Fig. 2. Distribution of the closed basins under study in the Parsęta catchment

Source: author's own study.

subboreal belt, in the geobotanical Central European Lowland-Upland Province (Kostrzewski 1998).

A characteristic feature of the Parsęta catchment refers to a considerable number of closed depressions, which – together with a large share of podsols – creates favourable conditions for the effective infiltration and increased retention of the catchment (Choiński 1998; Szpikowski 2010).

The conducted research is a part of an extensive programme covering monographic studies aimed to recognise the operation and variability of water circulation in catchments of closed evapotranspiration basins under different morpholithological conditions in West Pomerania.

Given these assumptions, 8 research fields were selected in the Parsęta catchment (Fig.1) (the upper Parsęta is number 1 in the south-eastern part of the upper catchment). Other (seven) study areas were selected from the south-east to the north-west, along with the Parsęta course and the system of subsequent upland levels. Within the chosen eight research fields with their total area of 834 km^2, a total of 2,065 closed basins were identified with their division into a closed evapotranspiration type (1,451) and an absorptive type (614). The various geographical environments of those basins, especially the geological structure, produce their two types differing in the mechanism of water circulation: evapotranspiration areas, where evaporation is the chief process balancing precipitation and totally closed, as well as absorptive areas, where infiltration is the chief process balancing precipitation and hence that only have no surface runoff (Drwal 1975; Drwal, Hryniszak 2003).

Research method

On the basis of some detailed cartographic analyses (topographic maps at a scale of 1: 10,000 – analogue and digital sheets) and field reconnaissance, the following six catchments of closed evapotranspiration basins were selected for stationary research: “Przeradź”, “Sławno”, “Krągłe”, “Sadkowo”, “Gruszewo” and “Rogowo” (with permanent or seasonal ponds in their floors). Similar mid-field land use was a characteristic to all the studied catchments. Three sites (“Przeradź”, “Sławno” and “Krągłe”) were located in the lake-land hump characterised by a great diversity of terrain. The other three sites (“Sadkowo”, “Gruszewo” and “Rogowo”) were located within the boundaries of VI, V and IV upland level, respectively (Fig. 2, Tab. 1).

Measuring equipment was installed at various stages of water circulation in the selected catchments. Measurements of, among others, surface and groundwaters were conducted with the application of electronic water level sensors (dippers made by SEBA) 3 times a day in the hydrological years 2007–2010. There was also a monthly sampling of groundwaters conducted for hydrochemical analyses and

Table 1. Location and basic morphometric parameters of the closed basin studied in the Parsęta catchment (without their catchments)

Site	Upland level	Length of basin	Width of basin	Elongation	Area
		[m]			[ha]
"Przeradź"	lake-land hump	45	40	1.13	0.57
"Sławno"	lake-land hump	50	40	1.25	0.63
"Krągłe"	lake-land hump	15	15	1.00	0.07
"Sadkowo"	VI	75	40	1.88	0.94
"Gruszewo"	V	90	75	1.20	2.12
"Rogowo"	IV	35	25	1.40	0.27

Source: author's own study.

water taken from ponds at the time (months) when water filled the depressions. Four times a year, in seasons with nice weather, hydrochemical mapping was conducted in 20 ponds in two subcatchments – the Kłuda and Młyński Potok – in the upper Parsęta catchment.

Hydrogeochemical types of water were determined in line with the Szczukariew method. The type of water was specified on the basis of the contents of seven basic ions: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^-, SO_4^{2-}, Cl^- and three additional ones: NH_4^+, NO_3^-, PO_4^{3-}, if their contents in water exceeded 20% meq [mval] in relation to the total of anions or cations (Macioszczyk 1987).

In order to recognise the lithological diversity, there was one-time sampling of sediments taken from drills during mounting 15 piezometers in 6 selected catchments of the depressions without outlets. Moreover, 7 soil exposures (open pits) were made in the "Przeradź" catchment. Sediments from the drills and all soil profiles were sampled and all samples were subjected to laboratory analyses. To mark sediments the commonly used methods were applied: sieving and the areometric procedure (developed by Casagrande, modified by Prószyński) (Dzięciołowski 1980).

Results and discussion

Characteristics of morphometric indicators

Morphometric indicators (their values) are treated as a relevant characteristic feature which defines the individuality of closed basins. Those with no surface runoff are usually small, concave landforms. On the basis of the collected documentation on absorptive depressions, the following parameters were calculated: length, width and depth as well as two relative measures: their elongation ratio and valley-floor depth/length ratio as well as for ponds and their catchments – length, width and their elongation ratio (Major 1999, 2009).

Closed absorptive basins are larger units (compared to ponds) and their length in the research fields in the Parsęta catchment ranged from 25 m to 850 m with an average of 123.7 m. In turn, ponds in terms of their length ranged from 5 m to 505 m, 42.8 m on average and their catchments – from 15 m to 640 m. The width of absorptive basins ranged from 15 m to 280 m, with an average of 66.1 m. The width of ponds themselves was 5 m–270 m , on average – 23.6 m and of catchments of these selected kettle-holes, from 10 m to 385 m.

Basins without outlets, apart from being small, are also relatively shallow. The depth of closed absorptive ones ranged from 1.4 m to 6.9 m, with an average of 2.2 m.

In turn, their depth/length ratio informs that the closer to zero its value, the shallower the depression. The average value of this relative measure for closed absorptive depressions selected in the Parsęta catchment was 2.39, and its extreme values, 0.39–7.81. It reflects a relatively high level of diversity of the studied depressions in terms of depth.

An elongation indicator informs – roughly – about a given closed basin (its shape) and its catchment, i.e. the closer its value is to zero, the more round this basin is (Kaczmarek *et al.* 1989). In the group of absorptive basins the analysed relative measure ranged from 1 to 21.25 (1.97 on average). These results provide evidence of the presence of round depressions (with a value of 1) and highly elongated ones, but close-to-round ones prevail.

In closed evapotranspiration basins there are also ones with a round shape, however their elongation indicator took lower values than the one for absorptive basins. For ponds it ranged from 1 up to 18 (2.0 on average) and for catchments of evapotranspiration basins – from 1 to 6 (1.9 on average).

In the whole Parsęta catchment some regularities can be identified in the spatial distribution of morphometric parameters which characterise the studied depressions. Absorptive ones are larger than closed forms but their number is lower compared to evapotranspiration ones; the smallest forms with no water are found in the south--eastern part of the catchment and their sizes increase contrary to their number per 1 km^2, together with a system of further upland levels so as to reach the largest sizes in the 4th study area at the border between the IV and III morainic levels. In turn, ponds with larger surfaces in closed evapotranspiration depression floors are found in the upper Parsęta catchment and in the 8th study area. Then, going north-west, their surfaces decrease, to increase again and reach the maximum values in the 4th, 5th and 7th test areas, i.e. in the V, IV and III upland levels. Lengths and widths of kettle-holes show a similar spatial distribution – just like surfaces; then in turn closed absorptive depressions have the maximum lengths and elongation indicator values in the upper Parsęta catchment and then their decline is reported towards the north-west (Major 2012).

Low values of the morphometric indicators and close-to-round shapes of closed depressions have an impact on water circulation in small catchments and emphasise the geographical individuality of closed depressions in relation to large river catchments.

Lithology

Lithology is another feature which specifies the geographical individuality of closed basins. The conducted analyses on granulation showed decreasing sediment permeability along the system of subsequent lower upland levels towards the Baltic Sea. There is a clear division into two groups of basins with their different lithology. Sands and slightly-loamy sands prevail at three sites ("Przeradź", "Sławno" and "Krągłe") located in the lakeland elevation. This lithology favours faster response to precipitation and accelerates water circulation. These are areas susceptible to infiltration and are characterised by infiltration capabilities. There is much less clayey sand and sandy clay here; in one of these catchments there was light clay and medium. In turn, at the other three sites ("Sadkowo", "Gruszewo" and "Rogowo") in the central part of the Parsęta catchment, in deeper profiles under strips of sands, clayey sands and sandy clays there were heavy clays, dusty clays, dusty silty clays, silty clays and heavy silty clays. These considerations contribute to the slowing of water circulation in the catchments and encourage retention.

The thickness of organic sediments deposited at the floors of the studied closed depressions was very diverse and ranged from 72 cm at the "Gruszewo" site in the V upland level to 300 cm at the "Sławno" site in the lakeland elevation, except for the "Sadkowo" site in the VI upland level where there were no layers of organic matter at its centre. The maximum percentage of organic matter in sediments in the floors of the studied basins ranged from 63.2% in the "Krągłe" catchment to 85.9% in the "Sławno" catchment in the south-eastern part of the Parsęta catchment.

Lithology also affected the distribution of both types of depressions in the Parsęta catchment. The largest number of closed depressions is found in the southern part of the Parsęta catchment characterised by a high diversity of terrain in the lakeland elevation area. The number of closed depressions decreases in the north-western direction. This arrangement is affected by their lithofacial variability. Along with the system of subsequent upland levels and decreasing sediment permeability, a high drop in the number of closed absorptive basins was reported. Hard permeable loamy morainic clays favour a larger number of closed evapotranspiration basins at lower levels and therefore a decline in their number in the north-west direction was not as high as in the case of absorptive ones (Major 2012).

The diverse lithology of closed basins affecting the rate of water circulation in small catchments and – above all – the greater thickness of organic sediments deposited at basin floors emphasise the geographical individuality of those basins connected with the operation of the current denudation system in post-glacial areas.

Soils

The studies of the spatial diversity of soils were conducted in the "Przeradź" catchment where 7 soil exposures (open pits) were made. In the analysed catchment of this closed depression there are several types of soil; their distribution is of ring-like nature and resembles rings around the depression at the floor of which there is a kettle-hole.

Around the catchment at slope tops in the watershed areas, apart from the western part of the catchment, **luvisols** (with their two subtypes: cutanic (standard) and cambic (brownish)) prevail. **Cutanic (standard) luvisols** are found in the northern part of the catchment of this closed depression and are a leading subtype in the type of luvisols. On the other hand, **cambic (brownish) luvisols** are found in the southern and eastern parts of the catchment of this closed depression and differ from cutanic (standard) luvisols by the following characteristics (the Polish Soil Taxonomy, 1989): the luvic level in these soils is highly developed and has a considerable thickness (60 cm–70 cm) and in the luvic ceiling level (E) there is intense weathering in its ceiling manifested by morphologically brown colouring of the re-shaped cambic level.

In the catchment slopes of this closed depression, apart from the western part, **specific deluvial soils** are found at the places of accumulation of deluvial muds transformed into soil via turf processes, at moderate humidity and with some grassy and herbaceous communities. These soils are generally shallow, with a layer of muds 30 cm–40 cm thick at most (Polish Soil Taxonomy 1989).

In the western part of the catchment in the watershed area and at the slope **brunic (rusty) arenosols** are found which are formed as a result of rusting. According to the Polish Soil Taxonomy (1989), morainic sands, outwash sands (close contact) and other little-sorted and little-washed sandy forms may make parent rocks of these rusty soils.

Three types of soil are found at a floor of this depression. Around the kettle-hole there are **mud-murshic histosols (mud-much soils)** at loose soils covered with deluvia. Mud-murshic histosols (mud-muck soils) are a sub-type of murshic histosols and belong to the order of post-bog soils. They get formed after de-watering of mud bog soils with a layer of silt with its thickness exceeding 30 cm. As a result of the progressive mineralization and shallowing of organic layers, these soils rapidly convert into mineral and muck soils. For these reasons, they occupy small areas (Polish Soil Taxonomy 1989).

Even deeper, at the edge of the kettle-hole itself **mucky soils** (which just like mud-muck soils) are a sub-type of murshic histosols and belong to the order of post-bog soils. They are organic soils with their surface layer (its thickness ranging within 10 m–30 cm) constituting a mineral or mineral-organic form. This is a form of mud (alluvial or deluvial) or anthropogenic origin (e.g. as a result of sanding). Plain peat (rarely any other form) lies deeper, often with some features of mucking, especially at lower thickness of its mineral over-layer (Polish Soil Taxonomy 1989).

There are **peat-mud soils** (which are a subtype of mud soils) at the basin floor under this kettle-hole. These are soils with blocked runoff of surface water. Limited aeration covered by the process of soil-forming reduces the humification of plant material which acquires the features of peat. An admixture of mineral sediments provides the mud-like character of this form. The profile can also contain peat inserts (Polish Soil Taxonomy 1989).

Their ring-like arrangement resembling circles towards the basin bottoms and the prevalence of organic soils in them are typical features of the spatial distribution of soils in small catchments of closed basins which emphasises the geographical individuality. It is connected with water migration and slope-based processes which lead to the washing of the material off the closed basin slopes and its sedimentation at their foot / floors.

Physical and chemical properties of surface and groundwater

Surface water in the closed evapotranspiration basins in the Parsęta catchment is characterised by high spatial diversity of chemical composition which depends on weather conditions, location, morphometric characteristics, land use and soil cover. In the period from 2006 to 2010, its pH values ranged from 4.1 to 10.1 and electrolytic conductivity, from 15.7 $\mu S \cdot cm^{-1}$ to 543.0 $\mu S \cdot cm^{-1}$. The hydrogeochemical types of water in the studied basins were two-, three-, or four-component ones, and their chemical composition was dominated by bicarbonate ions and calcium and – to a lesser extent – by sulphates, chlorides, sodium and magnesium.

The chemical composition of groundwater in the studied closed depressions was mainly conditioned by their lithology and depth of the first aquifer. It reflected the mineral composition of parent materials and their susceptibility to weathering. These were usually two-component waters but also three-, four- and five-component ones could be found. The chemical composition of groundwater was definitely dominated by bicarbonate ions and calcium, which was characteristic of the post-

-glacial lakeland zone. Slightly higher concentrations of sulphates, chlorides and sodium can also be observed.

In the vertical system, in the contact zone of precipitation with the terrain there was a more-than-twentyfold increase in mineralization (with its value for all mapped kettle-holes amounting to 118.02 $mg \cdot dm^{-3}$). Another increase in mineralization was observed in groundwater whereas its level depended on the depth of groundwater surface and ranged from 143.50 $mg \cdot dm^{-3}$ to 310.13 $mg \cdot dm^{-3}$, with an average for all the studied catchments in the Parsęta catchment of 236.88 $mg \cdot dm^{-3}$.

The volume of the supply of material dissolved into the studied catchments of the closed depressions was characterised by a high level of variability in time. Some regularities in the seasonal system for the studied stages of water circulation were demonstrated. There was a noticeable increase in pH for summer (vegetative) periods and a drop in pH in winter periods. There was a kind of interdependency – similar seasonal variability of electrolytic conductivity and HCO_3^-, Ca^{2+}, Mg^{2+} concentrations. Also another regularity was observed for biogenic components NH_4^+ and PO_4^{3-}, their concentrations were lower in summer and the highest – at the end of growing seasons. Climatic conditions, especially precipitation, and impacts of vegetation in the contact area of precipitation with the biosphere were the factors determining the above changes. For biogenic components, the duration of growing seasons was a relevant factor; seasonal changes in ionic concentrations in groundwaters were conditioned by the intensity of chemical leaching and weathering (Major 2012).

The above-described physical and chemical properties of surface and groundwater are characteristic of closed basins of the post-glacial zone; they emphasise the geographical individuality of these extremely valuable landscape elements of the West Pomeranian region. Closed basins are concave landforms and therefore increased concentrations of ingredients were found in their catchments which derived from the process of rock leaching and which chiefly originated from the chemical weathering of biogenic components related to the deposition of organic deposits in basin floors.

Conclusion

The geographical individuality of basins without outlets was examined in the paper in its several aspects. The paper emphasises the characteristic distribution of these basins in the Parsęta catchment and morphometric indicators, lithology of concave landforms, with organic sediments deposited at their floors, distribution of soils in their catchments showing the ring-like distribution and chemical composition of surface and groundwaters with their low and medium mineralization. In the case of the mapped small water bodies in the Parsęta catchment, the level of mineralization averaged 118.02 mg·dm^{-3}, and in the groundwater of the studied closed depressions it amounted to 236.88 mg·dm^{-3}. This value provides evidence of a low level of mineralization resulting from minor contamination of groundwater in the West Pomeranian region.

The analysed closed basins are permanent landscape elements in post-glacial areas but unfortunately steadily disappearing as a result of natural processes and artificial, excessive dehydration. They perform numerous functions: hydrological, ecological, geomorphological and economic. They are extremely valuable elements of the geographical environment in terms of geoecology, water management and environmental protection. Therefore, it would be advisable to take appropriate steps to protect these extraordinary landforms having an extensive impact on the current type of water circulation in the catchment.

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