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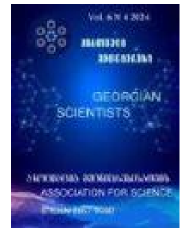

Problems of managing valuable natural wetlands in south-eastern Poland on the example of selected peatland reserves

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Abstract

Contemporary processes of anthropogenic transformation of the environment overlap with global problems related to climate change. These phenomena affect, among others, water resources and make the current methods of water management no longer correspond to current conditions. Research on the water balance of protected areas allows not only to properly plan changes in the method of water resource protection but also to link them with the protection of disappearing natural habitats and species.

It was assumed that the specific alimony catchment area remains without influences from the environment, and the amount of water retained by substrates other than peat is omitted due to their high infiltration coefficient. The water balance equation was used in the calculations, where: Inflow - [P + Hdp + ∆hg], Outflow = Retention [P + Hdp + ∆hg] - [E + Ho + ∆h'g] = +/- R, P - precipitation on the surface, Hdp - surface inflow of water from the catchment area, ∆hg - underground inflow, E - evaporation from the surface, Ho - surface runoff of water, ∆h'g - underground runoff, R - retention (water retained in peats). The values of evaporation and precipitation were assumed according to the current and available data of the Institute of Meteorology and Water Management. Vegetation studies were conducted based on the classic Braun-Blanquet phytosociological method [1]. Analysis and characterization of peatland habitats were adopted by the monitoring manuals [2, 3]. Three nature reserves located in southeastern Poland, in the Podkarpackie and Lublin voivodeships, were selected as research areas. The selected reserves are characterized by great spatial diversity and protect a wide spectrum of peatland vegetation.

The obtained results allow us to indicate peat bog areas as important in contemporary planning of water resources protection, however, due to the number of impacts to which they are subject, it is necessary to ensure an appropriate level of financing for nature protection so that it is possible to simultaneously protect natural habitats important for the European Union. The work carried out is part of the protection plans for the nature reserves mentioned above [4, 5, 6].

Keywords: peat bog, hydrology, nature conservation, nature reserve

Introduction

Human economy has continuously destroyed Aquatic and marsh ecosystems since the Middle Ages. These activities intensified especially at the turn of the 19th and 20th centuries, and continue to this day. This is mainly due to the intensification of agriculture, the construction of drainage systems, and the transformation of the land surface related to urbanization. The effect of these activities is the reduction of the area of these ecosystems and in many cases their complete disappearance. This process is compounded by the decrease in groundwater levels and changes related to climate warming - long-term droughts, torrential rains and short-lived, thin snow cover.

In light of these changes, the protection of aquatic and marsh ecosystems takes on particular importance. They retain and store water, improve and stabilize water conditions, enable the preservation of valuable natural habitats and rare plant species, and also create convenient places for breeding and feeding of invertebrates, amphibians, wetland birds and watering holes for birds and mammals, thus increasing biodiversity. Water resources are also a direct factor in determining growth, health, and intensive wood mass growth in stands. They also improve the conditions for agricultural activities, limit erosion, and mitigate climate change, especially in the form of temperature extremes. Natural water reservoirs, especially peatland complexes, capable of long-term water retention and its gradual release, are also of great value as elements of flood protection systems, especially in the context of the recent, catastrophic floods that covered a large part of Central Europe in the summer of 2024.

Types and importance of peat bogs

Water management, including the ability of natural habitats to retain water, cannot be planned in isolation from the specifics of these habitats. Peat bogs are wetland habitats in which organic matter accumulates, with a relatively constant excess of water. They usually form in places with difficult water drainage, on watersheds or on impermeable substrates. Peat bogs are a type of extrazonal vegetation, associated mainly with cool and temperate areas. The specificity of peat bogs also includes the lack of oxygen prevailing in the deeper layers of the peat deposit. The surface of peat bogs is covered with plants adapted to the permanently or periodically high humidity. Sometimes this vegetation is highly specific, for example when it is formed by Sphagnum sp. peat mosses, which are characterized by unlimited growth of apical meristems, while the lower parts of their stems gradually die off. The upper layers of the peat deposit form the so-called acrotelm, where the access of oxygen is quite significant. The deeper part, called catotelm, where the decomposition of plant tissues takes place, is practically devoid of oxygen and in most cases in typical peat bogs has a strongly acidic reaction, even below pH = 3.0. Peat bogs are considered to be wetlands where the accumulation of peat (of various types) reaches, depending on local conditions, 30-60 cm in thickness. The deepest peat bogs have a thickness of over 10 m of peat and up to 15 m of limnic sediment base. The most important contributors to peat formation are peat mosses, sedges, cotton grasses and shrubs from the heather family. In terms of phytosociology and habitat, three types of peat bogs can be distinguished: high, transitional and low.

High (raised) peat bogs, formed mainly by peat mosses, form tuft-valley complexes. Their hydrological balance is based on the dependence on precipitation waters, so they are ombrogenous peat bogs. Horizontal water movement is insignificant in them, and the entire peat bog takes on a convex, dome-shaped form. In terms of trophic status, they are dystrophic, poor in nutrients and strongly acidic.

The species composition here is quite poor and consists mainly of peat mosses Sphagnum sp., species from family Cyperaceae (sedges, cotton grass), Ericaceae (bog rosemary, cranberry, marsh rosemary), from genus Drosera insectivorous sundews and others. The vegetation of raised bogs belongs to the class Oxycocco-Sphagnetea and is protected as a priority habitat in the Natura 2000 network (code 7110*). They constitute about 6% of Polish peatlands and are located mainly in the north of the country, and scattered in the east and in the mountains.

Fig. 1. The carnivorous round-leafed sundew *Drosera rotundifolia* – a typical species of raised peat bogs.

Transitional peat bogs are supplied with both precipitation and water flowing from outside the peat bog and spring water. Vegetation of this type includes peat bog covers, sedge tufts and larger groups of other flower species. These peat bogs often form carpet covers on the surface of water reservoirs, made up of rhizomes of plants covered with peat mosses. Vegetation of this type belongs primarily to the Scheuchzerio-Caricetea nigrae class and is protected as a habitat in the Natura 2000 network (code 7140). They constitute about 4% of Polish peat bogs and occur both independently, in dispersion, and in raised bog complexes.

Low peat bogs are mainly supplied by inflowing waters. They occupy the lowest parts of slowly flowing river and stream valleys, floodplains and spring complexes. Horizontal water movement is very high. This type of peat bog is rich in humus compounds and mineral components originating partly from sediments and partly from water flowing into the peat bog. Their reaction is from slightly acidic to slightly alkaline. They are usually formed by reed beds, sedge beds, wet meadows and even alder forests, i.e. vegetation that is mostly not subject to legal protection and is quite widespread throughout the country. They constitute up to 90% of Polish peat bogs.

All types of peat bogs are subject to huge scale destruction, mainly as a result of drainage and melioration, agricultural expansion, expansion of development and water pollution.

Methodology and scope of research

It was assumed that the specific alimony catchment area remains without influences from the environment, and the amount of water retained by substrates other than peat is omitted due to their high infiltration coefficient. The water balance equation was used in the calculations, where: Inflow -

[P + Hdp + ∆hg], Outflow = Retention [P + Hdp + ∆hg] - [E + Ho + ∆h'g] = +/- R, P - precipitation on the surface, Hdp - surface inflow of water from the catchment area, ∆hg - underground inflow, E - evaporation from the surface, Ho - surface runoff of water, ∆h'g - underground runoff, R - retention (water retained in peats). The values of evaporation and precipitation were assumed according to the current and available data of the Institute of Meteorology and Water Management. Vegetation studies were conducted based on the classic Braun-Blanquet phytosociological method [1]. Analysis and characterization of peatland habitats were adopted in accordance with the monitoring manuals [2, 3]. Three nature reserves located in southeastern Poland, in the Podkarpackie and Lublin voivodeships, were selected as research areas: Imielty Ług, Piskory and The Spring of the Tanev River. The selected reserves are characterized by great spatial diversity and protect a wide spectrum of peatland vegetation.

Results

Imielty Ług Nature Reserve

The reserve includes a peat bog complex, part of which was transformed into fishing ponds at the end of the 19th century. After World War II, the state authorities took over ownership of this area and a State Fisheries Farm was established here. In 1990, a nature reserve was established with an area of approx. 800 ha. Currently, the complex's water reservoirs (the larger one - Imielty Ług and the smaller one - Radełko) are not used for economic purposes.

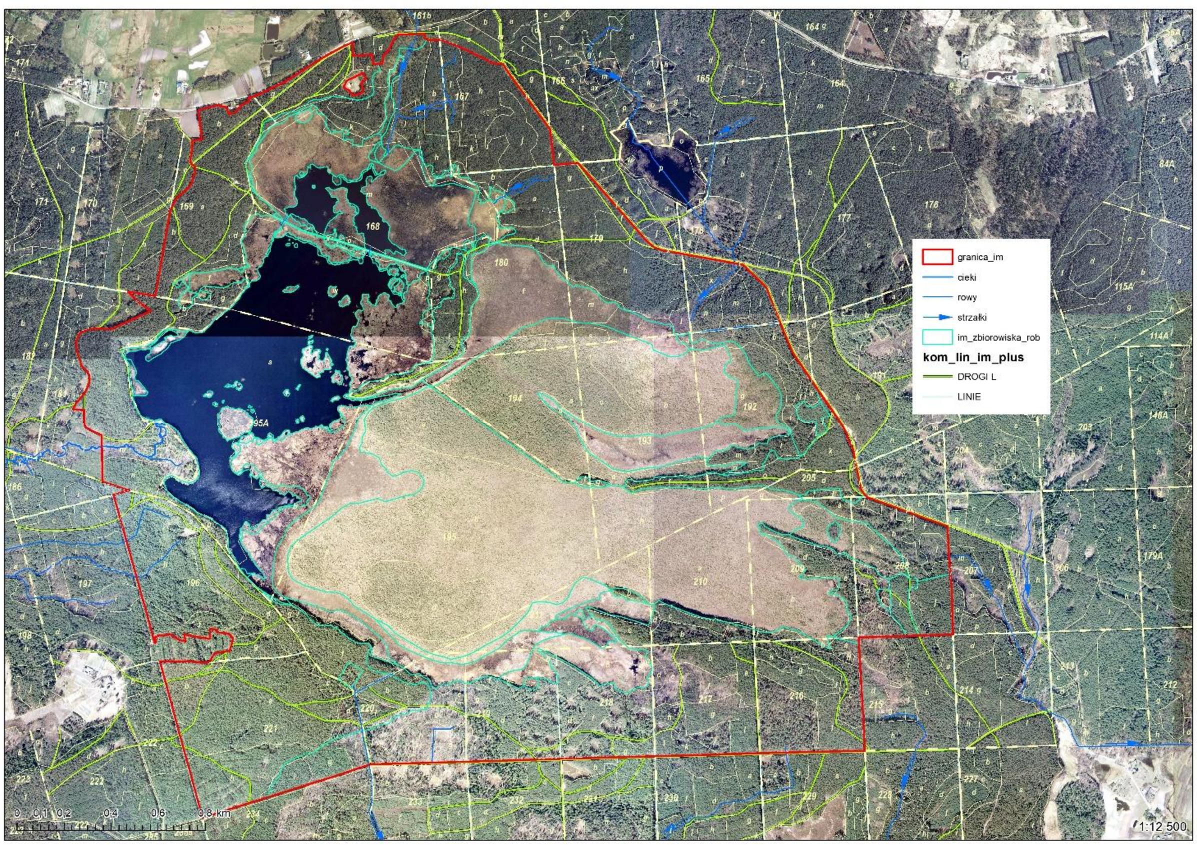

Fig. 2. Imielty Ług peat bog complex on the orthophotomap background.

The designated catchment area, which supplies the peat-reed complex and ponds of the reserve with rainwater, covered a total area of 16.5 km^2, which is 16,500,000 m^2 (including the part of the catchment area located within the reserve's boundaries of 6,610,000 m^2). Precipitation on the catchment area outside the reserve (9,890,000 m^2) is 6,369,160 m^3, and evaporation from this area is 3,461,500 m^3, the difference, excluding ground infiltration, constitutes an inflow from outside the reserve and amounts to 2,907,660 m^3. The area of the reserve located outside the catchment area of the pond-peat bog system is 1,390,000 m^2. Precipitation on this area is 895,160 m^3/year, this is the amount of water that flows out of the reserve or evaporates without affecting resources within the alimony zone of peat bogs and ponds. The area of the reserve in the catchment area is 6,610,000 m^2. Precipitation on the catchment area in the reserve is 4,256,840 m^3, and evaporation from this area is 2,313,500 m^3. The calculated value of the surface inflow, excluding infiltration (2,907,660 m^3) together with the value of precipitation on the reserve area, reduced by evaporation (1,943,340 m^3), assuming that the losses due to lateral seepage are balanced with the income from seepage, allow determining the value of water income - 4,851,000 m^3/year for the entire reed-peat bog complex and ponds.

The 2001 water use permit, based on hydrometeorological data from 1977, assumes year-round water collection, ensuring the operation of the pond farm, at the level of 2,065,202 m^3. However, this document assumed a water surface area of 127.2 ha, and an average depth of 0.55 m for Radełko and 0.85 m for Imielty Ług. Currently, the water surface, together with patches covered with floating vegetation, is approximately 71.7 ha, and the average depth, calculated based on 56 measurements made on 1 July 2022 in both ponds, was 0.95 m. The estimated reduction in the water level in Imielty Ług, based on observations and measurements of the water surface position relative to the shoreline traces (sediments, shore microstructures, vegetation position), was then approximately 0.6 m. The above data show that with the ponds fully filled, within their current boundaries, the volume of stored water would amount to 1,096,021.76 m^3. This value is close to the full volume of the reservoir calculated in 2001, i.e. 1,098,990 m^3, despite the reduction in its surface area due to the development of reed beds. Although in this situation, resulting from successional changes in reservoirs and the cessation of fishing, as well as climate change and the use of data from different periods, it is not possible to obtain full comparability of hydrological data, it can be assumed that the similarity of the volume of water stored in ponds calculated in 2001 and 2022, when they are completely filled, results from the high retention capacity of reed beds that have developed within the ponds over the last twenty years. The water surface of the ponds, together with the area of the identified reed beds, amounts to a total of about 125 ha, i.e. an area close to that reported in 2001. The difference between these numbers is probably small areas of shrubs, but their separation from the shrubs already existing at that time is not possible today. The reed beds shown here, as a form of low peatland habitats, were included in the calculation of retention waters in the peat bogs of the reserve.

Fig. 3. A drying reservoir on the surface of a peat deposit in the Imielty Ług nature reserve.

The reserve's retention resources are mainly shaped by the ability of peat bogs to store water, while other substrates are omitted here due to their high infiltration coefficients, which means that the water that seeps into them mostly supplies the peat bogs located here underground or percolates outside the catchment area. In substrates other than peat bogs in the reserve, there are no significant, retained free water resources. The peat bog basin of the reserve, together with the waters of the ponds and the peat bogs on their western and northern shores, which in the morphological sense are not connected to the main peat bog, has a total area of 4,291,982 m^2. To calculate peat resources and peat retention, the area of the patches of the following habitats located within the alimentation catchment area within the reserve was taken into account: raised peat bogs of the Oxycocco-Sphagnetea class, Vaccinio uliginosi-Pinetum marsh forests, transitional peat bogs of the Scheuchzerio-Caricetea nigrae class, peat reservoirs, reed beds of the Phragmitetea class and alder forests of the Alnetea glutinosae class. The area of the peat complex thus defined is 3,865,431 m^2. Taking into account the average depth of the peat deposit (2.13 m), calculated on the basis of 58 basic boreholes made in different parts of the complex, the total peat resources in the reserve were determined at 8,233,368.03 m^3. This calculation does not take into account the highly hydrated bottom sediments of reservoirs, the thickness of which does not exceed 0.5 m, and the resources of which are difficult to estimate precisely. The thickness of such sediments is included in the measurement of the depth of reservoirs. Full water saturation of peats of various types ranges from 75% in some low peats to even 95% in the case of most high peats and some transitional peats. Taking into account the percentage share of high and transitional peats in relation to low peats, the potential full saturation of peats in the reserve was assumed for further calculations at the level of 90%. With this assumption, the maximum volume of water that can be accumulated in peat bogs can be determined at 7,410,031.23 m^3. Based on measurements taken at 58 points, where the depth of the peat deposit was measured, the average depth of the groundwater table was also determined, which is about 27.01 cm. It was therefore assumed that this layer and the dried-out peat reservoirs of the reserve could contain an additional 1,044,052.91 m^3 of water and this value should be treated as the scale of peatland desiccation. At the same time, this amount of water is almost equal to the total demand for water to fill the ponds (1,098,990 m^3) shown in 2001 and exceeds the amount of water discharged during the emptying of reservoirs (902,863 m^3).

Piskory Nature Reserve

The reserve includes an artificial reservoir created in the mid-19th century. Work began in 1833 and continued with breaks until 1852. As a result of water damming, a pond with an area of 120 hectares was created. It was used as a fishing pond until World War II, and in 1944 it was nationalized. In 1990, as a result of prolonged drought, drainage works and a depression cone around the Nitrogen Plant in Puławy, the water surface disappeared. In 1993, work was undertaken to recreate the lake. In 1998, a nature reserve was established here. Today, only a relict water surface has survived. Most of the surface of the former reservoir is covered with reed vegetation of the Phragmitetea class, and in the eastern part also with alder forests of the Alnetea glutinosae class.

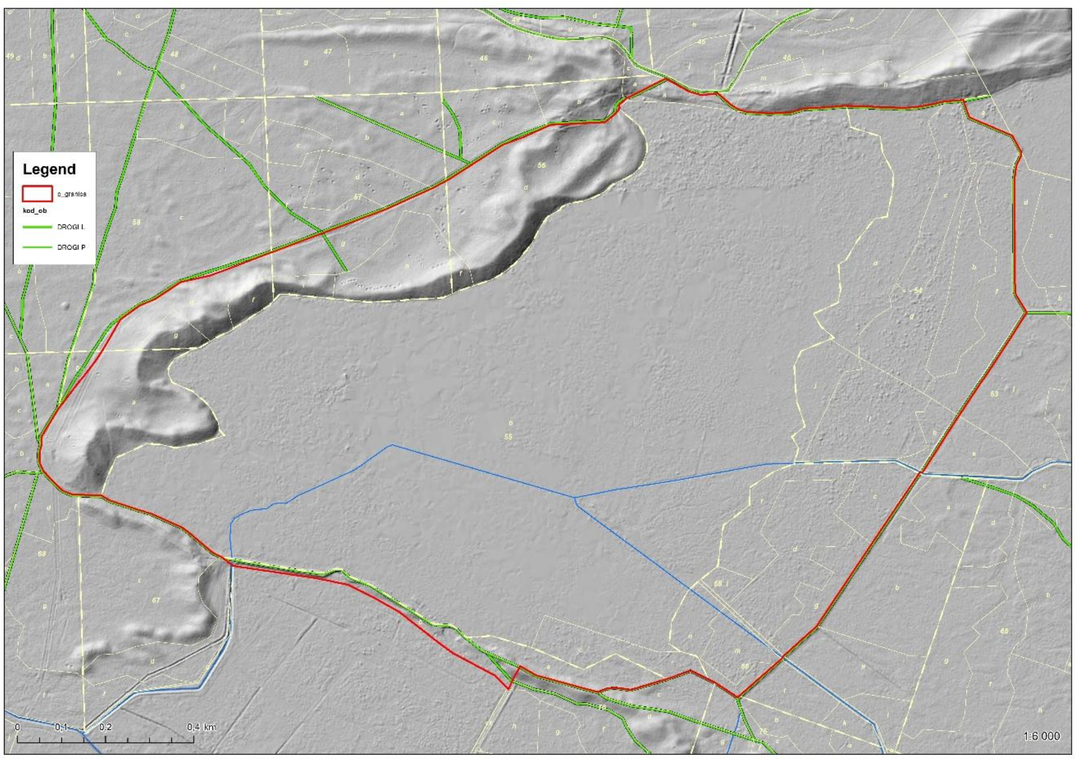

Fig. 4. Piskory nature reserve on the basis of the Digital Terrain Model.

The designated catchment area, which supplies Lake Piskory with rainwater, covered a total area of over 43 km2 (43,124,135 m^2, including the part of the catchment area located within the reserve boundaries of 1,850,502 m^2). The area of the catchment basin supplying the reserve, previously included in the calculations, requires comment. Namely, it included the catchment basin of the Duży Piotr stream up to the profile in the frontal dam of the reservoir and the Rabik catchment basin up to the branch of the Rabik II canal. The total area of such a unit was 84.7 km^2. This division of the catchment basin is included in the preliminary documentation (Kucharczyk 1996) and in the documentation from the monitoring of aquatic ecosystems in the area of Lake Piskory (Radwan 1997). This approach is incorrect and has a serious flaw, namely the inability to determine how much water from the Rabik catchment reaches Rabik II at the place where the streams branch. Moreover, during periods of drought, any flow in Rabik II disappears and it can only be assumed that this stream has only a narrow coastal catchment area. Small differences in the height of the terrain on the eastern side of the reserve do not allow for a certain determination of the catchment area boundaries and on significant parts of them, floodlands are formed after thaws and rainfall. The waters of these floodlands are additionally retained by dams built by beavers, slowed down in artificial streams by accumulations of organic matter and as a result, they only partially flow into the lake. The water resources remaining outside the reserve are partly subject to ground retention and partly to evapotranspiration. The water flowing into the vicinity of the embankment, locally accumulates in the vicinity of the embankment and flows into the reserve boundaries using culverts under the embankment, made on the beds of Duży Piotr, Rabik II, Duży Piotr II and on two other canals. For this reason, the inflow of all waters from the part of the catchment area located beyond the embankment should be treated as potential only, and at the same time it is not possible to precisely estimate the actual inflow.

Precipitation on the catchment area outside the reserve (41,273,633 m^2) is 24,805,453.4 m^3, and evaporation from this area is 14,445,771.6 m^3, the difference, excluding ground infiltration, constitutes an inflow from outside the reserve and is 10,359,681.8 m^3. The area of the reserve located outside the catchment area of the lake is 182,666.72 m^2. Precipitation on this area is 109,782.6 m^3/year, this is the amount of water that flows out of the reserve or evaporates without affecting resources within the alimony zone of the lake. The area of the reserve in the catchment area is 1,850,502 m^2. Precipitation on the catchment area in the reserve is 1,112,151.7 m^3, and evaporation from this area is 647,675.7 m^3. The calculated value of surface inflow, excluding infiltration (10,359,681.8 m^3) together with the value of precipitation on the reserve area, reduced by evaporation (464,476 m^3), assuming that losses due to lateral seepage are balanced with the income from seepage, allow determining the value of water income - 10,824,157.8 m^3/year for the entire complex surrounded by embankments.

Both the initial documentation of the reserve (Kucharczyk 1996) and the later documentation from monitoring works, including monitoring of aquatic ecosystems (Radwan 1997) and monitoring of ecological changes occurring as a result of renaturalization works (Radwan 1998) do not address the issue of water balance, but only provide the planned or expected volume of the facility. According to the authors of the preliminary documentation, the permanent surface of the water surface in Lake Piskory is 126 ha and allows for obtaining a volume of 1,000,000 m^3, and in the entire dammed area (175 ha) 1,690,000 m^3 of water. The assumed elevation of the water level was to be 123.6 m above sea level. The documentation from the monitoring of aquatic ecosystems indicates a maximum volume of 1,500,000 m^3, but with an elevation of 123.8 m above sea level. As part of the program "Renaturalization of ecological relations in the area of the Piskory reservoir" (Radwan 1998), the front dam was reinforced and raised to an elevation of 124.5 m above sea level. According to the authors of the study, this will allow for the storage of 1,500,000 m^3 of water with a water surface of 128 ha. However, obtaining this volume, with the assumed elevation of 123.8 m above sea level, is and probably was already unrealistic at that time, due to the lack of proper closure of the inter-dune gate in the northern part of the reservoir. The water elevation caused its surface overflow above the pipe culvert, because the ground level in this place is about 123.6 m above sea level.

Fig. 5. Residual water reservoir in the Piskory nature reserve.

Źródła Tanwi Nature Reserve

The area of the current reserve was not drained by drainage ditches until the mid-19th century, and the actual course of the Tanev began north of the reserve. The construction of the network of drainage ditches began in the 1860s and was probably completed in the 1930s. Since then, the springs of the Tanev have moved to their current location in the reserve. The reserve was established in 1998 on an area of approximately 186 ha.

The hydrographic network inventoried in 2020 is of a fully anthropogenic nature, overlapping the existing peatland reservoirs, which are the fundamental hydrographic units here. The existing system of drainage ditches, probably created in the 1930s, creates a drainage network, identical to the permanent outflow network. This network was intended to stabilize the outflow of water from the entire peatland system, thereby reducing their retention resources. The implementation of this task required connecting previously independent peatland facilities with ditches, dug both within the peatlands themselves and the dunes separating them. This required the creation of long ditch connections, and the drainage of peats, which have high absorption properties, a significant density of ditches in large reservoirs. A dense network of longitudinal, diagonal and transverse ditches was made in the main reservoir, from where a collecting channel, crossing the area from south to north, led water out of the reserve. This is the main drainage axis, draining most of the reserve's peat bogs. The second drainage axis includes a shallow ditch draining water from the eastern part of the reserve out of the reserve. These two main drainage axes are the only elements of the network of permanent water outflow from the reserve's peat bogs.

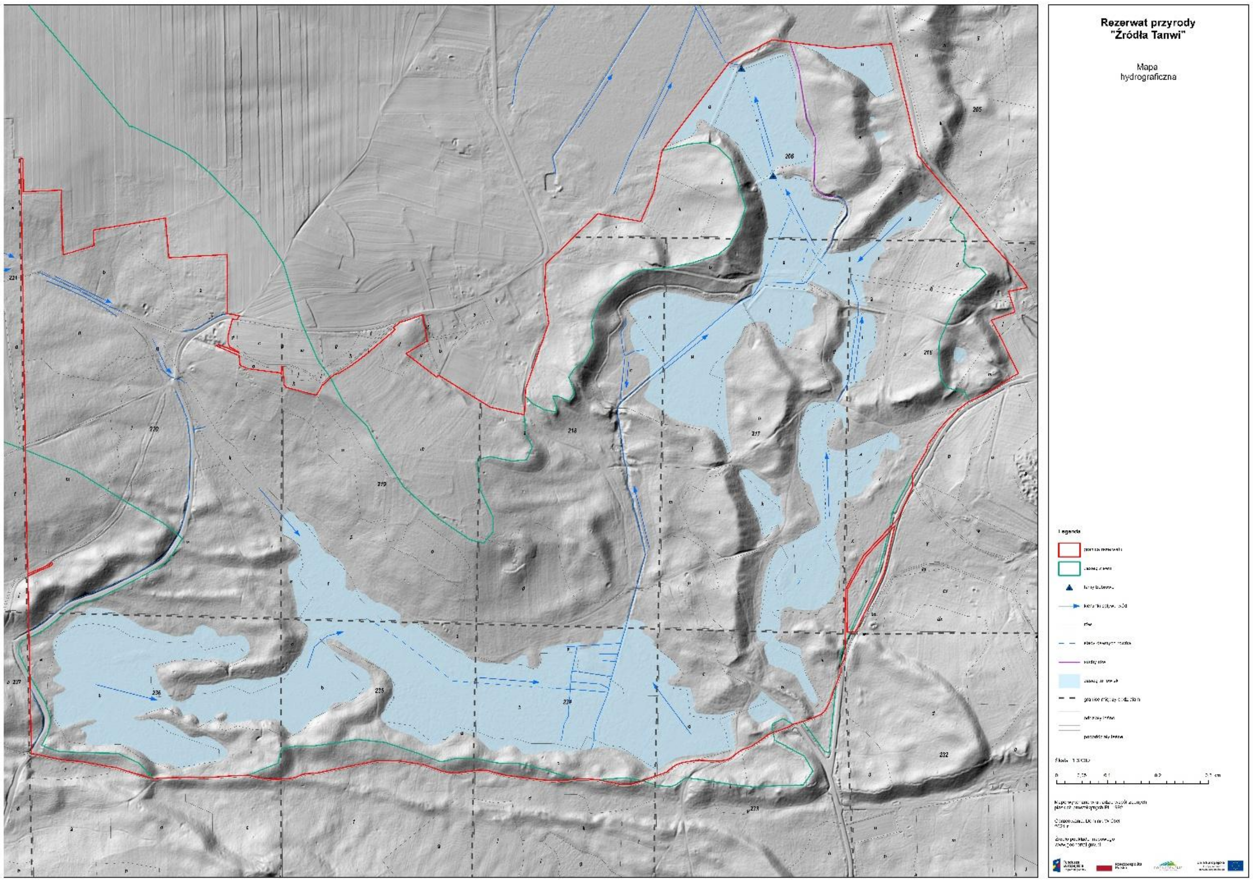

Fig. 6. The Tanew Springs nature reserve against the background of the Digital Terrain Model, including the location of peat bog reservoirs (light blue polygons), the system of drainage ditches (blue lines) and the direction of water flow (blue arrows).

Currently, these axes are not clearly visible. The reservoirs are permanently flooded by beavers, but they have preserved traces of ditches in the vegetation layout. They are identifiable on the orthophoto map, but in reality these places are permanently filled with water, as are their surroundings.

Regardless of the main drainage axes described above, a ditch is dug between some parts of the complex, which can periodically drain water. However, during the research in the reserve, no such phenomenon was observed - this ditch, apart from the initial section, is dry. Roadside ditches are also periodic forms of drainage. Their presence is also important due to the barrier nature of the roads running along the eastern border of the reserve and crossing its western part. These roads significantly change the outflow of water on the surface of the terrain and the flow of groundwater.

Drainage ditches, both permanent and periodic, dug outside the peat bogs, have different sizes. Their upper width is between 1.5 and 3.0 m, while the bottom width is on average 0.8 m, with an average depth of 1.0 m below ground level. Ditches dug within peat bogs are usually heavily filled with sediments and organic material and their original dimensions cannot be precisely determined. They probably ranged from 1.0 m wide x 0.5 m deep to 2.0 m x 1.0 m. The dimensions of roadside ditches depend on topographic conditions, in places reaching a width of 3.0 m at a depth of 1.5 m at the top of the embankment. The introduction of a drainage ditch system into the system of originally drainless reservoirs has significantly increased the area covered by organized drainage. Although a significant part of the reserve is a catchment area with periodic drainage, during long-term dry weather and high summer temperatures, the drainage network contributes to the drying of a significant part of the peat bogs.

It should also be noted that the creation of a network of artificial ditches also forced a change in the direction and intensity of natural surface runoff.

The hydrographic network, formed by a system of drainage ditches, has 5,556 m of ditches, including a dry ditch with a length of 338 m, obliterated and partially overgrown ditches for 1,343 m and roadside ditches for 1,348 m. Taking into account all categories of ditches, the density of the hydrographic network is almost 29.9 m/ha, and excluding road ditches - 22.6 m/ha.

The average rainfall of 685 mm is assumed as the annual average from the meteorological station. The designated catchment area, supplying the peatland system of the reserve with rainwater, covered a total area of 268 ha, which is 2,680,000 m^2, including 1,118,100 m^2 outside the reserve. Rainfall on the catchment area outside the reserve is 765,898.5 m^3, and evaporation from this area is 411,460.8 m^3, the difference, excluding ground infiltration, is an inflow from outside the reserve and is 354,437.7 m^3. The area of the reserve located outside the catchment area of the peatland system is 295,200 m^2. Rainfall on this area is 202,212 m^3/year, this is the amount of water that flows out of the reserve or evaporates without affecting resources within the catchment area of the peatlands. The area of the reserve in the catchment area is 1,561,900 m^3. Rainfall on the catchment area in the reserve is 1,069,901.5 m^3, and evaporation from this area is 574,779.2 m^3. The calculated value of surface inflow, excluding infiltration (354,437.7 m^3) together with the value of precipitation on the reserve area, reduced by surface runoff and evaporation (495,122.3 m^3) allow us to determine the value of water income - 849,560 m^3/year. The reserve's retention resources are mainly shaped by the ability of peat bogs to store water, while other substrates are omitted here due to their high infiltration coefficients, which means that the water that seeps into them mostly supplies peat bogs underground. In substrates other than peat bogs in the reserve there are no significant resources of free water.

The reserve's peat reservoirs have a total area of 452,100 m^2. Taking into account the average depths of the peat deposit in individual reservoirs, the total peat resources in the reserve were determined at 835,511 m^3. The full saturation of peat with water, which was assumed at 90%, allows us to determine the maximum volume of water that can be accumulated in the peatlands at 768,159.9 m^3.

Based on measurements taken at 50 points, located in seven main peatland reservoirs, the average depth of the groundwater table was determined to be 25.14 cm. It was therefore assumed that this layer and the open water floodplains of the reserve could contain an additional 102,292.143 m^3 of water.

The calculated difference between the values of the inflow and the evaporation and retention of the peatlands is approximately 747,267.9 m^3 and constitutes the probable surface runoff from the reserve. This means an outflow of approximately 0.0237 m^3/s.

Surface runoff is mainly carried out by a drainage ditch. Precise measurement of the runoff intensity was not possible, because its final section is blocked by a wide beaver lodge, and then it passes through a causeway with a footpath, behind which it spreads in a wide strip with an average depth of 0.30 m. Based on the approximate cross-section of the runoff and the water velocity, the runoff intensity was measured in September and January. It amounted to 12.3 and 5.1 l/s (0.0123 and 0.0051 m^3/s), respectively. These values are lower than calculated, but they result from measurements outside the period of the most intense rainfall. The drainage ditch located more to the east is largely shallow and conducts water only during the period of intense rainfall, probably collecting it from a small area of the adjacent dune. During the summer field inspections and in September 2020, at the end of the summer rainfall period, this ditch was flooded in its estuary section, but no water flowed out of the reserve at that time.

Discussion

Imielty Ług Nature Reserve

The calculated difference between the assumed water volume of the ponds when completely filled and the volume of revenue, reduced by evaporation, is 3,752,010 m^3 per year, which is 50% of the calculated water deficit in the peat bog. According to the hydrological study from 2001, the available flows amount to 2,767,290 m^3 throughout the year, and at the same time, no water is assumed to be released from the discharge devices, except for the period from 1 to 25 October, assuming that the inviolable flow below the reservoir, of 10 l/s, will be provided by seepages from the Imielty Ług pond.

The above calculations and the historical data cited indicate an extremely unbalanced water balance of the complex. In order to supplement the water shortages in the peat bog, it should be remembered that also within the ponds, there is a volume reserve that is difficult to estimate, because it varies throughout the year, resulting from too much water runoff in recent years, in relation to the inflow and precipitation with increased evaporation. This reserve can be even over 430,000 m^3. Determining the safe level of runoff for the peat bog can only take place after restoring the full impoundment in the reservoirs, i.e. after they are filled to the elevations: for Radełko 182.6 m above sea level, and for Imielty Ług 182.4 m above sea level, and also after supplementing the demonstrated water shortages in the peat bog. The main factors influencing the reserve's water shortage are, apart from climate change and succession processes occurring in the peat bogs, also basing water use permits on outdated data and the practice of water theft. The latter phenomenon results from the general shortage of water resources. The owners of fish ponds located above the reserve are taking out too much water, while those located below the reserve are destroying the damming facilities and generating excessive runoff from the peat bogs.

Piskory Nature Reserve

The lake's retention resources are quite difficult to estimate, because the specificity of the reed vegetation causes the formation, even in periods of extreme drought, of a complex mosaic of tussocks, planes, waterlogged depressions and residual water reservoirs with a difficult to estimate share of sedge and reed peat. To calculate the retention capacity of the lake, it is necessary to assume the homogeneity of the bottom and adopt the average thickness of peat deposits, which, calculated based on 20 measurements taken in different parts of the lake, was 0.95 cm. With the further assumption that the fully water-saturated form of the peats present here usually contains about 85% water, then on the surface of 127 ha, in the water-peat layer with a volume of 1,206,500 m^3, there is 1,025,525 m^3 of retained water. Even with optimistic assumptions regarding the possibility of water damming in accordance with studies from 1997 and 1998, the reservoir can permanently store only about 500,000 m^3 of water above the extremely low level observed in 2022. An analysis of the actual possibilities of retaining water in Lake Piskory and releasing it through the frontal dam can only be carried out after the construction of the northern embankment, closing the lake to the elevation of 124.5 m above sea level.

Źródła Tanwi Nature Reserve

It seems that the water balance of the peat bogs is moderately unbalanced. In average rainfall years, they are partially drained, and the deficiencies are supplemented during years with rainfall values exceeding the average of 685 mm. In the reference period of 1951-1991, as many as 23 average annual rainfall values are significantly lower than the multi-year average, and only 16 are significantly higher. Due to this situation, it is necessary to build gates in the indicated locations, allowing for a moderate increase in the water level in the peat bog reservoirs. The existence of a network of drainage ditches, even those partially overgrown with vegetation, causes constant, excessive drainage of the complex.

Conclusions

The water resources of peat bogs in selected reserves are an excellent example of natural natural objects, transformed anthropogenically to a limited extent, which have enormous water retention capabilities. Their significance includes not only the capture of excess water during periods of rainfall but also the gradual release of accumulated water during periods of drought. The potential retention volumes shown for individual objects may constitute an important element of the local water balance and indicate the undervaluation of peat bogs and wetlands in general in modern water resources management. At the same time, treating peat bogs as objects accumulating water is not incompatible with providing them with appropriate protection, taking into account their natural values. On the contrary - both goals are consistent with each other. The protection of peat bogs requires providing them with appropriate hydration, hence maintaining their retention role becomes at the same time an action aimed at protecting natural habitats and species.

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