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NATURAL AND ANTHROPOGENIC CHANGES OF STANDING WATER BODIES IN WEST POLESIE (EAST POLAND)

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Abstract
The article presents changes in the surface area of standing waters in West Polesie, East Poland. The study was based on the analysis of the content of archival topographic maps of Poland at a scale of 1:10,000, presenting the situation from the early 1980's, and ortophotomaps and satellite scenes from the years 2010-2014. The objective of the analysis was the determination of the direction of the transformations, as well as the presentation of results conflicting with the opinion commonly adopted in Europe on the proceeding decline of the surface area of water bodies. The number of objects and their surface area evidently increased over the last three decades. This resulted from the co-occurrence of natural factors and human activities, both destructive, and those aiming at the restoration of the Old Glacial hydrogenic areas unique at the European scale.

Keywords: water bodies, climate fluctuations, hydrographic cartography

1. INTRODUCTION

The Łęczna-Włodawa Lake District and the Middle Bug River Valley are subregions of West Polesie, constituting the westernmost fragment of a large European region of Polesie. Both of the subregions are included in the western part of the West Polesie Transboundary Biosphere Reserve.

The environmental attractiveness of West Polesie has encouraged researchers from a number of fields to perform intensive environmental studies. They have been documenting transformations of biotic and abiotic elements of the region for more than a century. The first of the papers concerned peatlands and the accompanying lakes (Kulczyński, 1939, 1940), and a thorough study of several tens of lakes of the Łęczna-Włodawa Lake District (Wilgat 1954). A number of monographs and papers have appeared so far, with content related to standing surface waters, constituting the primary element of hydrogenic landscapes (Chmielewski&Chmielewski, 2008; 2010; Chmielewski&Piasecki, 2010; Harasimiuk et al., 1998; Kowalewski, 2012; Osowiec, 2011; Radwan et al., 2002; Michalczyk et al., 2003).

The study area occupies 1,181 km^2. Water bodies together with the surrounding peatlands are the most important elements of Old Glacial hydrogenic landscapes. The system of standing surface waters is dominated by lakes with a small area, but varied depths. The area of standing waters also includes that of retention reservoirs in the western and central part of the Łęczna-Włodawa Lake District (Dawidek et al. 2004; Mięsiak et al., 2005), complexes of fishing ponds established on the weakly permeable soils of the northern and western part of the area, and peat-pits, pools and small ponds, excavation pits, and sinkholes developed as a result of exploitation of aggregates and hard coal (Chmiel et al., 2002; Michalczyk&Zarębski, 1995; Michalczyk et al., 2007; Pęczuła et al., 2014). The area is distinguished by the occurrence of numerous small water bodies of varied origin, particularly anthropogenic.

The first research paper concerning the identification of small water bodies with an area of less than 1 ha in the West Polesie Transboundary Biosphere Reserve was published in 2013 (Sender et al., 2013). It identified approximately 3,000 such objects with varied origin, area, and character of their immediate surroundings.

Along with climate changes, large areas originally occupied by lakes were transformed into peatlands. The area of the Łęczna-Włodawa Lake District has been subjected to measures aimed at draining excess water and obtaining land for agricultural activity for more than 200 years (Wilgat et al. 1997; Mięsiak et al., 2005, Sposób & Turczyński, 2009). In the second half of the 20th century, the western and central part of the Łęczna-Włodawa Lake District was incorporated into the largest in Poland melioration system of the Wieprz-Krzna Canal (Janiec, 1993; Michalczyk, 1994). In the 1980's, hard coal mines were established at the south-western boundary of the region.

2. METHODS

The objective of the study was the analysis of changes in the surface area of standing waters performed in two temporal aspects with different degree of humidity. The situation from the years 1980-1984 was analysed based on topographic maps at a scale of 1:10,000. For the years 2010-2013, ortophotomaps and satellite scenes were applied. The water bodies were digitalised in the GIS environment. Areas with identical distance from shores of the water bodies were identified. The areas of the buffers between equidistants were used for the determination of the density of water bodies (Wilgat, 1966). Changes in the water surface area were also presented in basic fields with an area of 1 ha. The field verification of selected objects was performed in July and August 2013.

Precipitation is the primary factor guaranteeing the permanent character of a water body. The determination of the distribution of precipitation in the study period and the period preceding the analysis is the basic requirement permitting drawing accurate conclusions. The mean annual precipitation in the study area in the years 1955-2013 amounted to 550 mm. The period included 36 dry years (Fig. 1) and 26 years with precipitation exceeding the mean value. The lowest precipitation, below 75% of the mean value, was recorded five times, in 1959, 1961, 1969, 1977, and 1982. High precipitation, exceeding 125% of the mean total, occurred eight times, in 1966, 1974, 1980, 1997, 2000, 2001, 2009, and 2010. A long sequence of dry years, from 1981 to 1991, resulted in drying out of a number of small water bodies. Excess precipitation in the years 2005-2010, and particularly the very high precipitation of two consecutive years 2009 and 2010, resulted in filling them with water again. The first of the periods mentioned above is documented by topographic maps issued in 1984. The second one is documented by satellite photographs commonly available on geoportal.pl, and by high-resolution scenes of Google Earth.

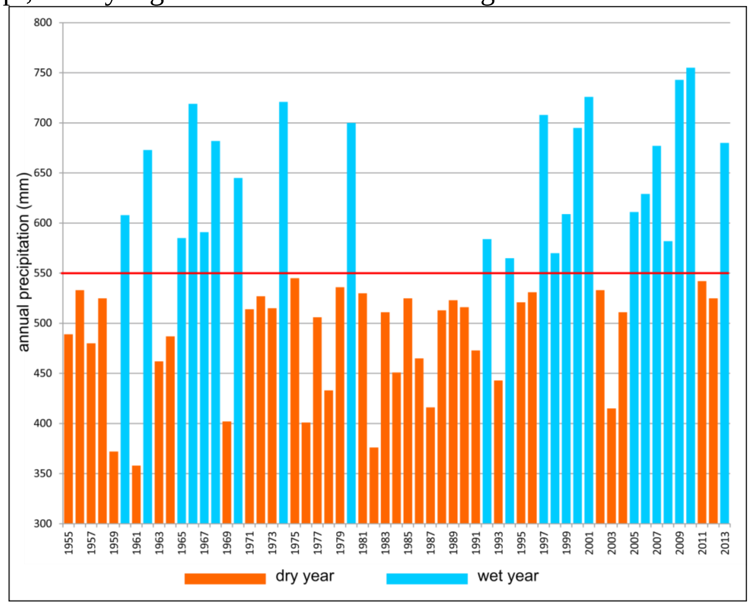

Figure 1. Annual precipitation recorded in the Łęczna-Włodawa Lake District in the years 1955-2013 (precipitation station in Garbatówka)

3. RESULTS AND DISCUSSION

The study area, located outside of the range of the last glaciation, is distinguished by small surface areas of particular water bodies. The terrestrialisation processes, slower than in the northern part of Poland and Europe, resulting from the evolution of lakes towards peatlands and gyttja bogs, caused the transformation of large water areas into smaller water bodies. Their number today exceeds 4,000 (Table 1). The mean area per water body in the years 1980-1984 amounted to 1.43 ha, and three decades later 1.33 ha. The area criterion for lakes adopted in Poland is 1 ha. Smaller water bodies are called ponds (Choiński, 2007). Small water bodies are also recognised as "ponds" in foreign literature (Downing et al., 2006; Rouen, 2001). According to the Pond Conservation Group (1993), small water bodies are objects with an area of less than 2 ha, maintaining water surface for at least 4 months in a year.

In the early 1980's, the study area included 2,427 such small water bodies. Three decades later, their number increased to 3,968. They were dominated by peat-pits and small ponds (Table 2). The number of small ponds has been dynamically increasing since the 1990's.

Table 1. Water bodies of the Łęczna-Włodawa District

Type of water body	1980-1984			2010-2013		
	Number of objects	Area (ha)	Contribution of water area of a given type in the group of water bodies	Number of objects	Area (ha)	Contribution of water area of a given type in the group of water bodies
lakes and lakes transformed into retention reservoirs	60	2,754.30	74.3	65[1)]	2,852.00	50.8
fluvial lakes	308	56.98	1.5	362	145.99	2.6
ponds	271	752.30	20.3	1,258	985.70	17.6
peat-pits	1,880	139.20	3.8	1,830	172.30	3.1
excavation pits and sinkholes filled with water	20	1.50	0.04	43	20.90	0.4
overflow areas				353	1,414.20	25.2
other water bodies	51	3.14	0.1	295	18.91	0.3
total	2,588	3,707.42	100.0	4,206	5,610.01	100.0

1) The increased number of lakes in the period 2010-2013 results from filling several fragments of the gyttja bog in place of the former Lake Laskie

No considerable changes in the surface area of lakes have been observed over the last three decades (Fig. 2). They are the most stable among all of the studied types of water bodies. Limnic systems the most prone to transformations are located in the south-western part of the Lake District. They are affected by the activity of hard coal mines. Deformations of sinking ground result in changes in the direction of surface and underground water runoff.

Table 2. Areas of limnic objects in the years 1980-1984 and 2010-2013

Type of water body	Documentation from the years	Area (ha)											
		Mean value	<0.01	0.01 – 0.1	0.1 - 1	1 - 5	5 - 10	10 - 50	50 - 100	100 - 500	500 - 1000	min	max
			Number of objects										
lakes and lakes transformed into retention reservoirs	1980-1984	45.90	0	0	4	9	8	22	10	7	0	0.576	458.20
	2010-2013	43.88	4	3	3	8	8	20	12	7	0	0.00142	478.47
fluvial lakes	1980-1984	0.185	26	195	75	10	1	0	0	0	0	0.00511	9.014
	2010-2013	0.403	9	160	161	27	4	1	0	0	0	0.00282	11.81
ponds	1980-1984	2.558	12	105	69	47	17	21	1	0	0	0.00609	51.94
	2010-2013	0.783	29	825	321	45	14	21	2	1	0	0.00400	104.55
peat-pits	1980-1984	0.074	111	1,434	325	7	0	1	0	0	0	0.00441	14.19
	2010-2013	0.094	140	1,322	353	13	2	0	0	0	0	0.00088	6.50
excavation pits and sinkholes filled with water	1980-1984	0.067	2	15	3	0	0	0	0	0	0	0.00668	0.42
	2010-2013	0.486	9	23	8	2	0	1	0	0	0	0.00180	14.65
overflow areas	1980-1984	*	*	*	*	*	*	*	*	*	*	*	*
	2010-2013	4.006	30	152	122	28	11	8	0	1	1	0.00161	783.17
other water bodies	1980-1984	0.061	7	38	6	0	0	0	0	0	0	0.00435	0.64
	2010-2013	0.064	11	241	42	1	0	0	0	0	0	0.00364	1.84
total 1980-1984			158	1,787	482	73	26	44	11	7	0		
total 2010-2013			232	2,726	1,010	124	39	51	14	9	1		

* not marked in topographic maps

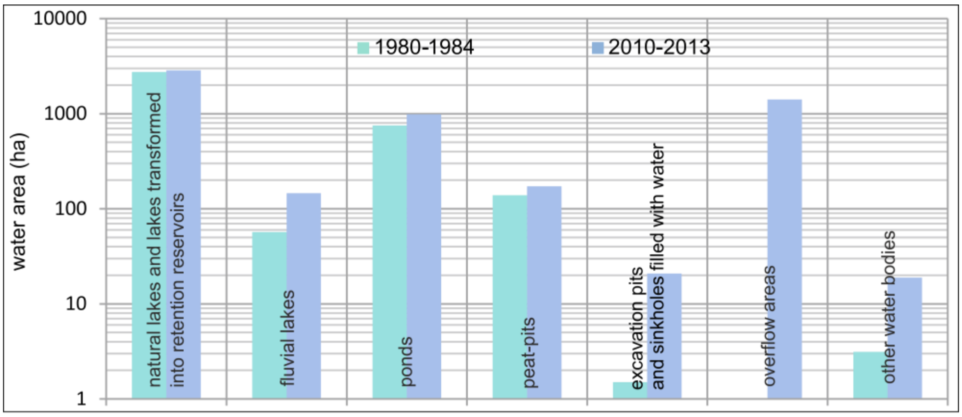

Figure 2. Total water area by basic types of water bodies

In the years 2010-2013, as a result of increased precipitation and restoration measures, depressions were occupied by overflow areas. They particularly developed in the Polesie National Park.

In the years 1980-1984 in the Łęczna-Włodawa Lake District and the Middle Bug River Valley, lakes constituted 2.33% of the area, and the total contribution of all of the water bodies reached 3.14%. In the years 2010-2013, the values increased to 2.41% and 4.75%, respectively. The values are approximate to the mean value for the lakelands of north Poland, amounting to 2.39% (Choiński, 2007).

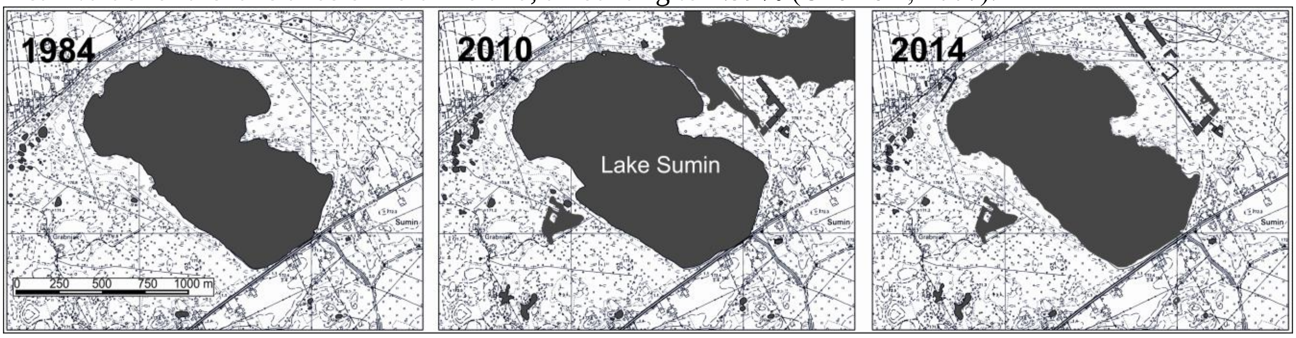

Figure 3. Dynamics of changes in the area of astatic and static water bodies in the vicinity of Lake Sumin

The studied water objects are categorised into static and astatic in terms of their permanence (Kajak, 2001). The former group includes natural lakes and lakes transformed into retention reservoirs. Their morphometric parameters, and in the case of retention reservoirs – water supply control, guarantee continuous filling of the basin with water. Astatic water bodies are distinguished by repeatability, cyclical or non-cyclical character of changes, and particularly the unpredictability of the functioning of their ecosystems (Fig. 3). This group includes natural shallow lakes, fluvial lakes, waterholes, beaver ponds, overflow areas resulting from damming with vegetation and peat-pits, fishing ponds, garden pools, post-excavation pits, fire water reservoirs, and sedimentation tanks.

Peat-pits are the most commonly occurring astatic water bodies in the study area (Fig. 4). Peat excavation was usually conducted on boundaries of large peatland complexes. In the 20th century, in periods of crisis related to wars, excavation of peat as fuel for domestic purposes was very common. This resulted in the development of a network of water bodies with a mean depth of up to 2 m. The activity of the peat industry in Poland reached its peak in the first half of the 1950's. Peat is currently excavated for gardening purposes. In the years 2010-2013, 15 peat-pits had an area of more than 1 ha (including two with an area exceeding 5 ha), and 140 very small objects did not exceed the area of 0.01 ha.

The commonly assumed tendency of decline of the surface area of water bodies in Europe related to human economic activity and climate changes was reversed in the western part of Polesie over the last several years.

Changes in the density of standing surface waters were presented by means of the equidistant method, i.e. determination of buffers of identical distances from water (Wilgat, 1966). The mean distance from a water body determined by the method in 1980 amounted to 580 m. Three decades later, it decreased to 385 m (Fig.5). The largest distances between water bodies occur in the northern and eastern part of the study area, in zones of highly permeable aeolian sands and sands with gravels.

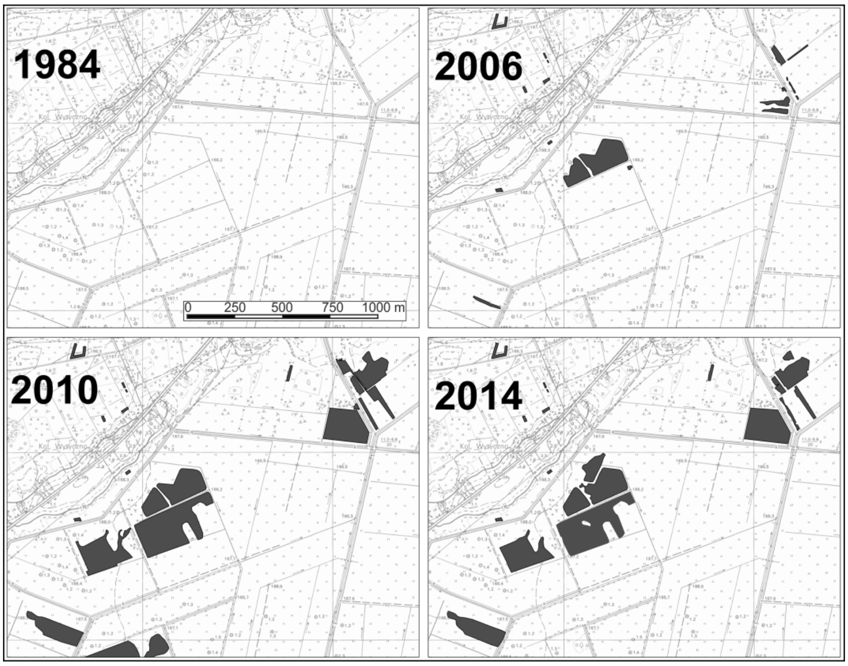

Figure 4. Increase in the area of peat-pits as a consequence of currently intensified peat excavation at the boundaries of the Krowie Bagno peatland

The synthesis of the spatial variability of changes in areas occupied by water bodies was prepared by means of quantitative analysis in a matrix with fields of 1 ha. The analysis result was presented in a diagram (Fig. 6) and spatial cartographic image (Fig. 7).

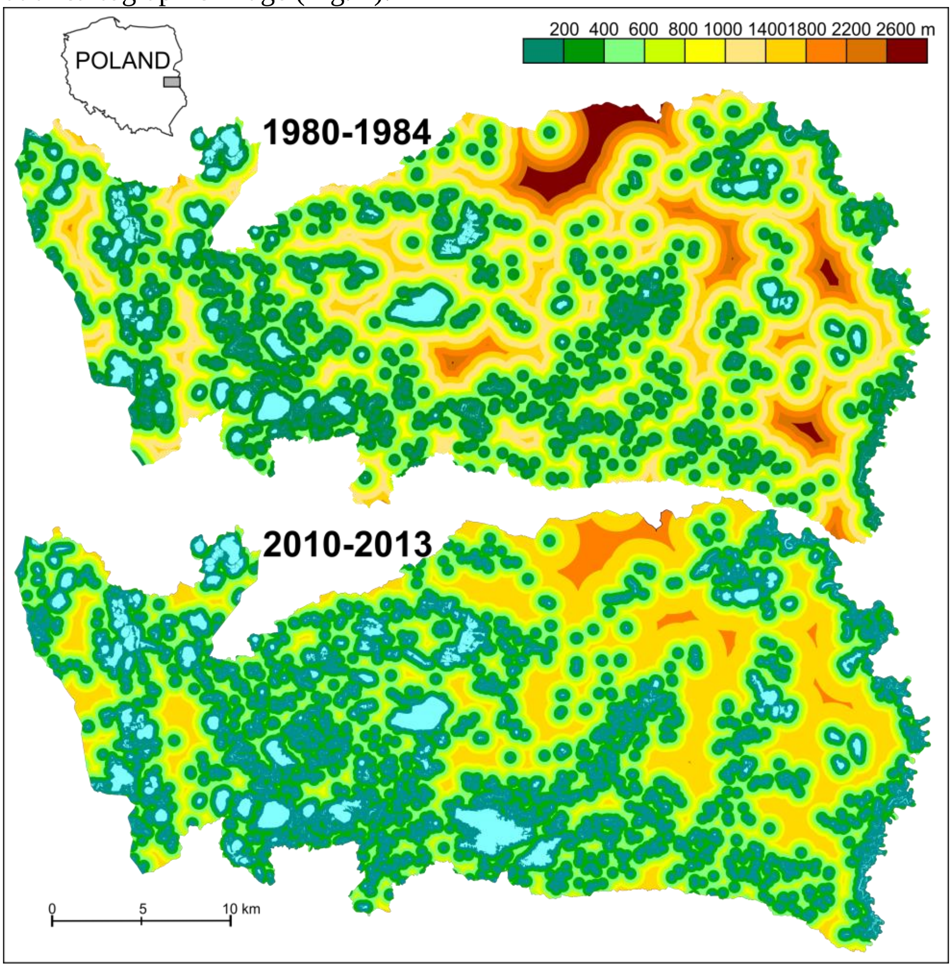

Figure 5. Zones of distances from water bodies – equidistant map

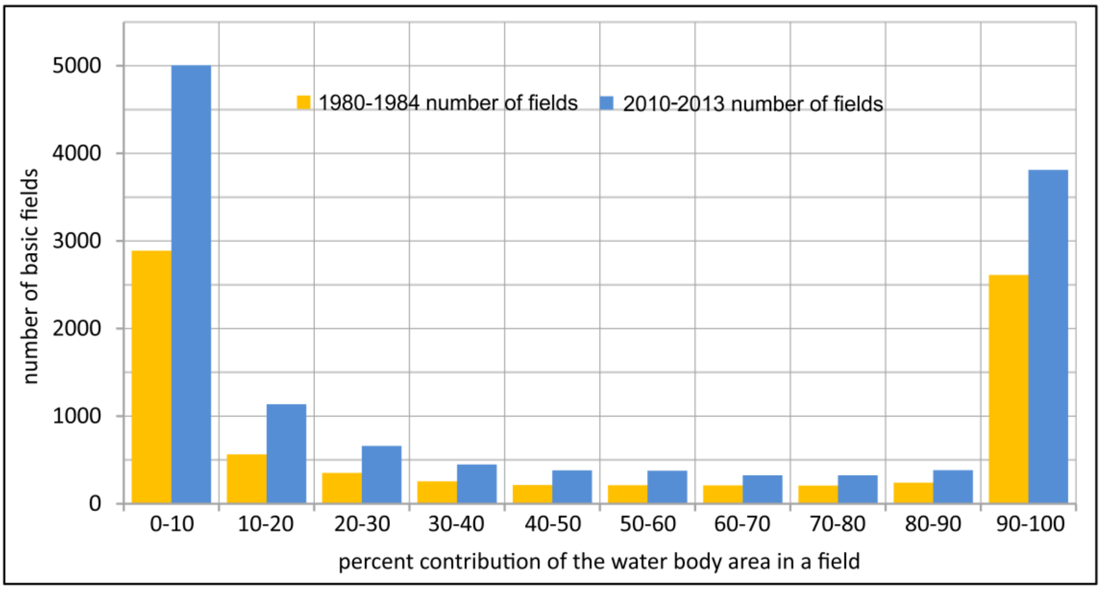

Figure 6. Number of basic fields in classes of contribution of standing surface waters

The difference map (Fig. 7) presents three areas (A, B, and C) with a considerable increase in the surface area of standing water bodies. Water bodies in the Polesie National Park (A, B) developed as a consequence of restoration works involving damming water runoff from originally closed-drainage areas incorporated into the melioration system in the 20th century. In area C, water bodies developed as a result of the destructive activity of man. Some of them are flooded depressions resulting from mining land deformations. Others are currently developed peat-pits.

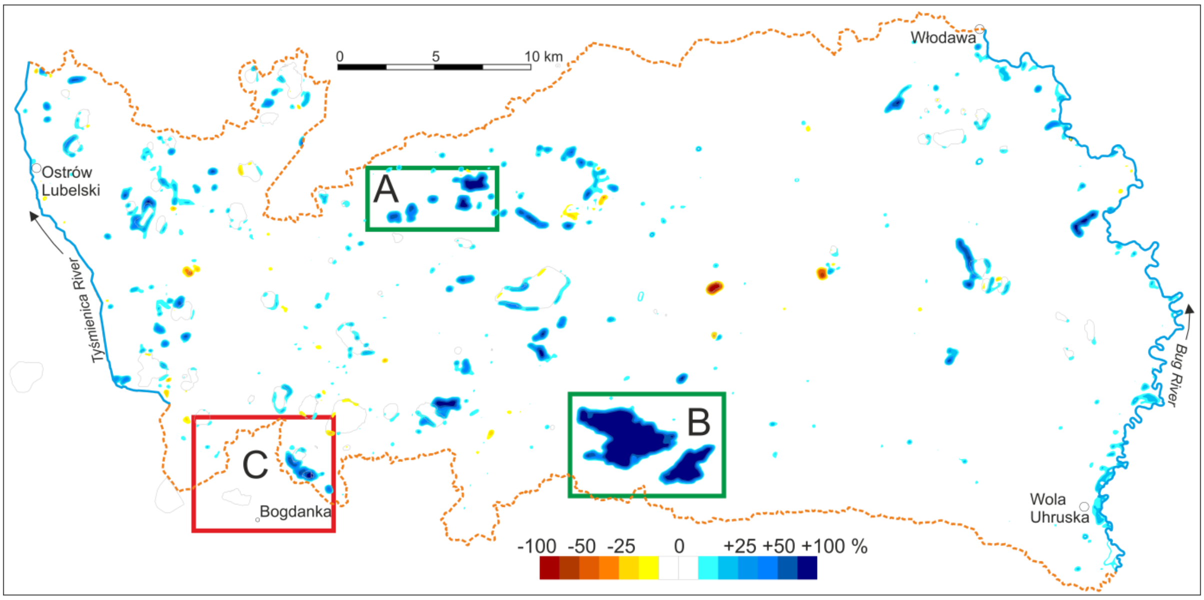

Figure 7. Difference map of the surface area of standing waters of the Łęczna-Włodawa Lake District and Middle Bug River Valley in the years 1980-84 and 2010-2013
A – peatlands in the southern part of the Polesie National Park subject to restoration measures, B – meadows and ponds in the northern part of the Polesie National Park subject to restoration measures, C – zone affected by the activity of hard coal mines

Water bodies, particularly small, play a considerable role in the preservation of biodiversity in West Polesie (Chmielewski&Piasecki, 2010). The objects have become a habitat and place of reproduction of valuable endangered animals. In the scope of the *Programme of protection and restitution of European pond turtle (Emys orbicularis) in Poland*, a number of small water bodies have been established in the eastern part of the study area for the purpose of reintroduction of the species. Moreover, the water bodies have become a suitable ecosystem for swamp minnow *(Eupallasella percnurus)*. Both of the species are under strict species protection in Poland, and they are included in the IUCN Red List of Threatened Species.

4. CONCLUSIONS

The determination of the rate and direction of transformations of water resources accumulated in natural and artificial surface water bodies must be preceded by the analysis of the conditions of precipitation. Lack of information on precipitation preceding the terms of hydrological analysis frequently results in unjustified conclusions. Such a procedure will permit the identification of natural and anthropogenic factors determining the functioning of water bodies.

In the early 1980's, 2,588 water bodies (static and astatic) were recorded in the study area, occupying a total area of 37.1 km^2. After the first decade of the 21st century, the study area included 4,206 objects with a total area of 56.1 km^2. The increase in the number of standing surface water objects has natural and anthropogenic causes. A natural factor raising water resources is increased precipitation and its specific distribution in time. Over the recent years, many natural depressions were occupied by overflow areas resulting from restoration measures, particularly in the Polesie National Park (Pikunas&Kobielas, 2007). The growing population of Eurasian beaver (*Castor fiber*) largely contributes to their development. The Middle Bug River Valley with approximately 300 fluvial lakes is a hydrological area unique at the European scale. Its water resources are subject to continuous natural changes.

The excavation of hard coal by the caving method results in land deformations in the south-western part of West Polesie. Water accumulating in sinkholes develops dynamically changing anthropogenic water bodies.

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