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Accelerated peatland disappearance in the vicinity of the Konin brown coal strip mine

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Abstract

In the Powidzki Landscape Park, there are 150 peatlands of a total area of 1,250.2 ha. On its edge, brown coal strip mines are in operation, causing deep land drainage that resulted in a drastic (up to 5 m) lowering of the water table in lakes and accelerated peatland disappearance. To determine the extent of the process, a comparison was made of the types of surface soil layers and their ash content in 20 peatlands determined in 1957–1965 and in 2017. They are located in the farmland lying the closest to the strip mine, Jóźwin IIB, and in woodland lying further away. The results were compared with those for a peatland in Skulsk, which was not affected by the negative impact of the strip mine. Fen peat, occurring there about 55 years ago has largely turned into grainy moorsh. In the 20–50 cm layer, an ash content has grown almost twofold, while in part of the peatlands organic soils have changed into mineral and organic-mineral ones. The greatest changes have occurred in the farmland. In all Park peatlands, grasslands have contracted threefold, while the area of forests and woodlands has grown fivefold. Today, about 10% of the peatland area is taken up by arable land of which there was none before.

Key words: *brown coal mining, lakes degradation, landscape park, peatland utilization change, peatlands disappearance*

INTRODUCTION

Caused by drainage, the process of peatland disappearance has been recently described in detail [ILNICKI, SZAJDAK 2016]. The process is accelerated by a very deep lowering of the water level in a peatland. Such a situation is observed in the cone of depression of the brown coal strip mines in Bełchatów and Konin. In the area of the Konin strip mine (KWB Konin), extensive investigations have been carried out, concerning possible climate changes in the vicinity of Kleczew in the second half of the 20th century [KĘDZIORA 2011; OWCZARZAK, MOCEK 2004; STACHOWSKI *et al.* 2016], hydrogeological determinants of the impact range of the cone of depression caused by the strip mine drainage system [ILNICKI, ORŁOWSKI 2006; 2011; NAWALANY 1998; PRZYBYŁEK 2011], and changes in water levels and the morphometry of lakes located on the Warta and Noteć watershed [ILNICKI *et al.* 2012; ILNICKI, ORŁOWSKI 2006; 2011; KĘDZIORA 2005; KUNZ *et al.* 2010; MARSZELEWSKI *et al.* 2011; PIASECKI, SKOWRON 2014].

Geobotanical investigations of peatlands neighbouring on brown coal strip mines within the Powidzki Landscape Park (PLP) were carried out in 1957–1965 [CZYŻEWSKI 1961; KALIŃSKI 1957; KRASNODĘBSKI 1958; MAREK 1960; PAŁCZYŃSKI 1961; PIASECKI 1965; TOŁPA 1960; WĄS 1960], using uniform methodology. A synthetic description of the structure and location of all PLP peatlands studied earlier [ILNICKI *et al.* 2017] includes also the results of the study of peatland vegetation made for the purpose of drawing up a protection plan for a Natura 2000 area [CHMIEL 2007]. An overview of peatland studies in the entire Noteć River valley was published by OKRUSZKO and CHURSKI [1962]. The river's western branch (Western Noteć) rises in the northwest of the PLP.

In the early 21st century, MOCEK and OWCZARZAK [2003], within the Konin–Turek coal field, marked off an almost 900-hectare zone (zone III, peat and moorsh soils) in which the water level had considerably lowered due to the deep drainage of brown coal strip mine surroundings, causing soil degradation. They recommended a study of the soils. OWCZARZAK and MOCEK [2004], leaving out organic soils, proved that in mineral arable land located close to KWB Konin pits (15,000 ha), the major source of water for crops was precipitation.

Only KOMISAREK *et al.* [2011] studied organic soils (histosols) in the vicinity of the Jóźwin IIB strip mine on locations showed on a soil-agricultural map with a scale of 1:100,000. Results from this area differ greatly from the results of the above-mentioned detailed geobotanical studies [ILNICKI *et al.* 2017]. Only part of the soils studied by these authors, located north of the Budzisław Kościelny–Wilczogóra road, belong to the PLP. These authors report that due to the deep drainage of organic soils, their mineralization rapidly advanced, organic mass density increased, deep levels of grainy moorsh developed, while organic formation thickness decreased. Significant admixtures of mineral deposits were found in peatlands occurring outside of the PLP, in Kaliska–Kopydłowo and Budzisław Kościelny–Koziegłowy Lake troughs, whereas the smallest admixtures of this kind were found in the trough situated between Lake Salomonowskie and Lake Kosewskie in the PLP. The water level in organic soils dropped to 1 m below the ground level and more. The greatest degradation was observed in organic soils lying close to strip mine pits.

Peat-moorsh soils in the cone of depression of the brown coal strip mine in Bełchatów were studied by FRĄCKOWIAK and FELIŃSKI [1994] and GAWLIK [1994] in 1979–1990. They described a network of deep fissures arising under these conditions and preventing farming, as well as an increase in volumetric density of moorsh and peat, accompanied by significant unfavourable changes in the porosity and water retention of these soils. The impact of the intensive drainage of peat-moorsh soils in the vicinity of the brown coal strip mine in Bełchatów on the mineralization of organic nitrogen compounds was studied by TURBIAK and MIATKOWSKI [2008]. After 25 years of drainage, in Rogowiec and Borowo, on MtIIIc soils, the ash content of a moorsh layer was 26–30 per cent at a depth of 0–20 cm and 20–21 per cent at a depth of 20–40 cm. The deep drainage of these soils makes a mineral nitrogen content ($N\text{-}NO_3$ and $N\text{-}NH_4$) grow two- to threefold in comparison to soil which is supplied with groundwater. This is a result of the increased thickness of the layer where the mineralization process occurs and the elongation of the periods when soil is favourably oxygenated. These processes are the most intensive at a level of 0–20 cm. UZAROWICZ *et al.* [2014], having studied changes in soil-water conditions in the vicinity of the strip mine in Bełchatów, found that after 20 years of intensive drainage, peat soils (fens), due to over drying, changed into mineral-moorsh and mucky, while grasslands were changed into arable land.

The purpose of this study was to determine selected effects of the long over drying of organic soils, caused by the draining of KWB Konin strip mines. One of such effects is the disappearance of peatlands in the PLP and the Natura 2000 area 'Gniezno Lakeland', PLH 300026.

STUDY AREA

In numerous strip mines located in the area of Kleczew, north of Konin, brown coal has been extracted to fuel for the Gosławice and Pątnów power plants since 1957. Brown coal extraction in the now reclaimed strip mines Kazimierz Południe, Kazimierz Północ and Jóźwin IIA continued from 1962 to 2005, while since 1998, a much deeper strip mine, Jóźwin IIB, has been in operation. All these strip mines are located close to the Warta and Noteć watershed, that is, in a part of the country with the lowest climatic water balance in a growing season and intensive farming [KOZYRA *et al.* 2009]. The drained strip mines were 50–60 m deep, or even 70 m in Jóźwin IIB, lying the closest to the drainage divide and the trough of Budzisławskie and Wilczyńskie lakes. This brought about the development of a vast cone of depression and the desiccation of many peatlands in the PLP.

The border of the PLP (24,600 ha) runs only 4 km north of the deepest strip mine, Jóźwin IIB (Fig. 1), while the trough of Wilczyńskie-Powidzkie lakes, forming part of the Natura 2000 area 'Gniezno Lakeland', PLH 300026, in the vicinity of Budzisław Kościelny, lies only 6 km from the edge of this strip mine. The Natura 2000 area 'Gniezno Lakeland' is composed of five separate complexes of which two large troughs are situated in the PLP. These are the source reaches of the Western Noteć, from Lake Niedzięgiel (Skorzęcińskie) to Gębice, and the through in which large lakes are located: Powidzkie, Budzisławskie, Wilczyńskie, Suszewskie, Kownacko-Wójcińskie and Ostrowskie. Of these, only Powidzkie lake belongs to the Warta drainage basin.

To determine the range of the negative impact of strip mine drainage, the KWB Konin has determined the extent of the cone of depression which, however, does not encompass any lake! Not does it take into account a continuous water table lowering in many lakes located within the impact area (Fig. 1). For the greater part of a year, the direct runoff of the Meszna

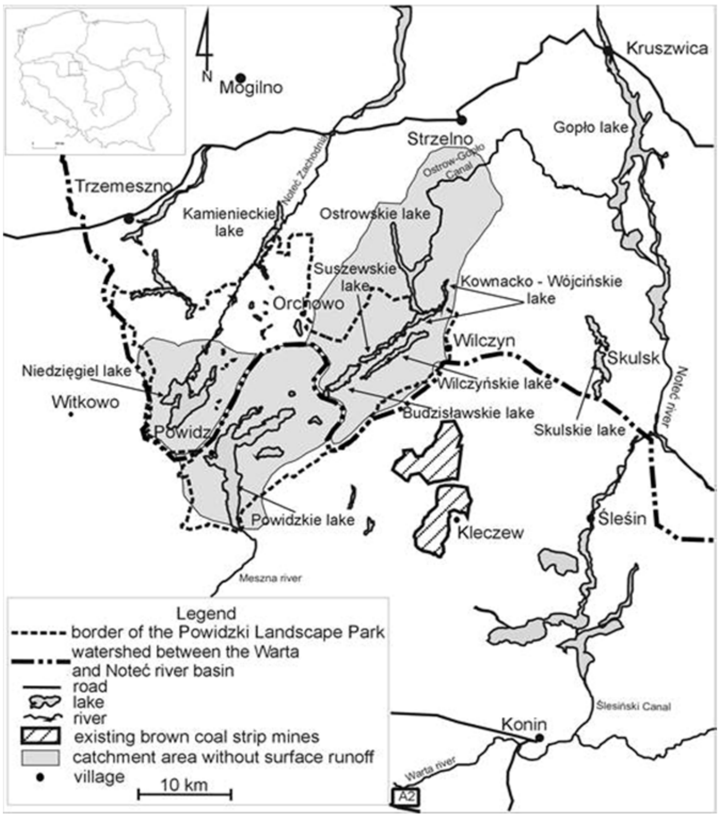

Fig. 1. Powidzki Landscape Park and their surroundings; source: own elaboration

River, flowing out of Powidzkie lake, has ceased as have runoff from Lake Niedzięgiel (Skorzęcińskie), in which the Western Noteć has its source, and runoff from Lake Ostrowskie, via the Ostrowo–Gopło Channel, in the direction of Gopło lake. Drafted for the Konin provincial governor, the forecast of strip mining impact on surface and underground water [NAWALANY 1998] showed, however, that the impact of the drainage of Józwin IIB would reach much further northwest and would cover the surroundings of Niedzięgiel lake and the other lakes. The territory from which runoff was no longer observed in 2010 [ILNICKI, ORŁOWSKI 2011] covered about 350 km^2 (Fig. 2), concentrated mainly around the trough of Budzisławskie–Ostrowskie lakes, and bore out the forecast of the depression cone range given by NAWALANY [1998]. Yet, the KWB Konin, did not revise the course of the depression cone border and ignored also the evidence that there was a hydrological window on the northern shore of Lake Suszewskie (bore hole No. 292), connecting the surface and subcoal layers of sand. Had the hydrological model taken into account the existing connection between these two layers, the range of the cone of depression would have been greatly enlarged in comparison to that adopted in studies commissioned by the KWB Konin. The border of the cone of depression is marked by the lowering of the groundwater level by 1.0 m, which means that only Powidzkie and Niedzięgiel (Skorzęcińskie) lakes (Tab. 1) are outside its range but, no doubt, under its negative impact.

All the brown coal strip mines are located in the Warta drainage basin, but their negative impact on water tables in this drainage basin affects only Powidzkie lake, the largest and deepest in this area, the runoff of which may be regulated by a weir. The vast majority of lakes are located in the Noteć drainage basin (Ostrowo–Gopło Channel and Western Noteć). Interestingly enough, Budzisławskie and Suszewskie lakes were changed into a joint storage reservoir in the 1970s. It has become inoperative, however, because the water level in the lakes has dropped below the bottom of the dam. In the early 21st century, water stopped flowing from Kownacko-Wójcińskie lake to Ostrowskie lake. There has been no runoff from Ostrowskie lake to the Ostrowo–Gopło Channel for many years already, while a runoff from Niedzięgiel lake ceased in 1990 and from Powidzkie lake in 2005. Only at very high winter water levels does water flow between lakes. Some of the lakes are divided into separate basins and in several islands have appeared.

The original water table level in lakes was determined by the Inland Fisheries Institute in Olsztyn in 1965 (marked on topographic maps with a scale of 1:10,000). It is only to these values that the changes due to mining activity, which occurred in 1965–2016, can be reasonably referred (Tab. 1). Since 1965, water level in many local lakes has dropped considerably, which is most unfortunate as they are places for the recreation of the region's population and the most valuable portions of areas covered by nature conservation named earlier. The greatest drop of a water table level (4.4–5.0 m) took place in lakes Wilczyńskie and Suszewskie, a smaller one (2.35–2.7 m) in Budzisławskie, Ostrowskie and Kownacko-Wójcińskie lakes, while the smallest drop was observed in Niedzięgiel (Skorzęcińskie) lake (0.84 m) and Powidzkie lake (0.28 m). The Regional Directorate for Environmental Protection (Pol. Regionalna Dyrekcja Ochrony Środowiska) in Poznań, by the environment decision of 16 December 2009, recommended that in the future the original water table level be lowered by 1.0 m in the lakes located in the Budzisławskie-Ostrowskie trough and held that the water table level had not dropped in lakes Powidzkie and Skorzęcińskie. A similar step was taken by the mayor of the commune and town of Kleczew in the environment decision of 28 January 2010. The decision adopted mean water levels in the lakes of this commune recorded in 1992–2003 and ignored their state in 2010.

To compare the effects of the ground- and surface-water level lowering, the current study covered also peatlands bordering on the Skulskie lakes of which one had been regularly measured and did not show any significant changes of annual mean water levels. It lies

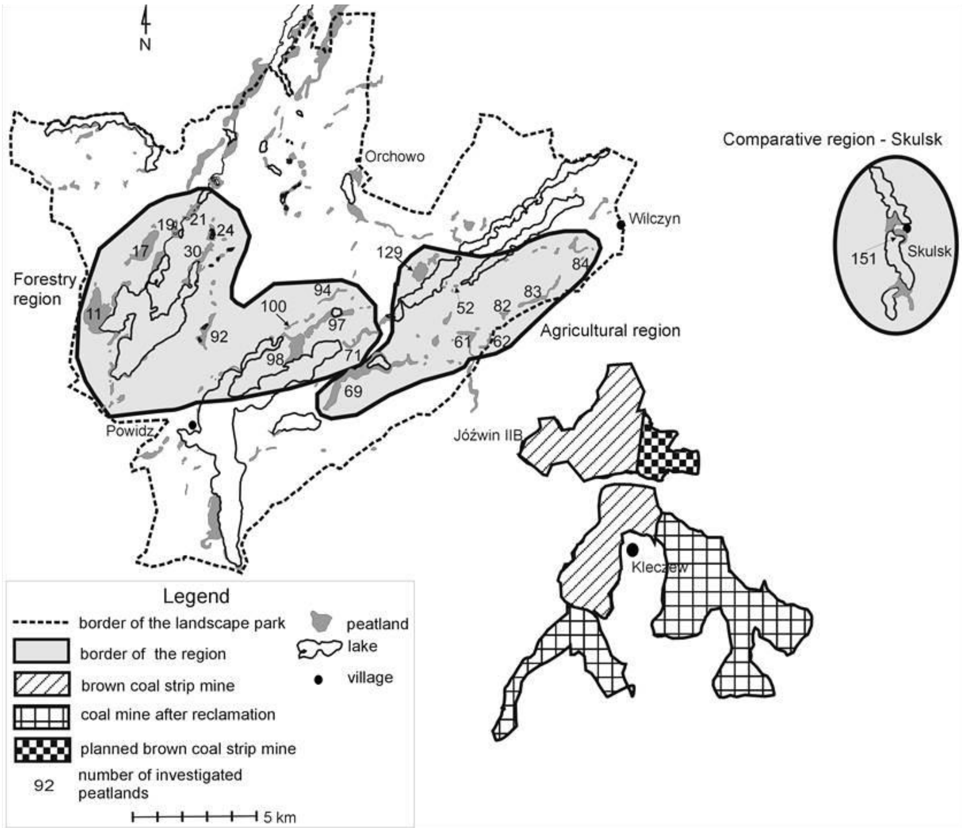

Fig. 2. Peatlands in the Powidzki Landscape Park and near the Lake Skulski; source: own study

Table 1. Change of mean annual water level in lakes being under the negative impact of the brown coal mines near Kleczew

Lake	Annual mean water level in the lake m a.s.l. Kronstadt							Reduce of the water level, m
	1965	1995	2000	2010	2016	acc. to RDOŚ [2007]	acc. to Urząd Miasta i Gminy [2010]	
Budzisławskie	99.4	98.54	98.60	97.56	97.05	98.4	98.4	2.35
Kownacko-Wójcińskie	98.9	97.99	98.07	96.96	96.20	97.8	97.8	2.70
Niedzięgiel (Skorzęcińskie)	104.0	103.19	103.49	103.29	103.16	–	–	0.84
Ostrowskie	98.9	97.53	98.18	96.51	96.22	97.8	–	2.68
Powidzkie	98.35	98.16	98.05	98.01	98.07	–	–	0.28
Suszewskie	99.2	98.29	97.78	96.65	94.20	98.2	98.2	5.00
Wilczyńskie	99.0	97.96	98.08	95.84	94.60	98.2	98.2	4.40
Skulskie	85.9	86.10	86.01	86.21	85.47	–	–	0.43

Source: own elaboration based on the data from the Institute of Meteorology and Water Management and ILNICKI *et al*. [2012], ILNICKI and ORŁOWSKI [2011]; PIASECKI and SKOWRON [2014].

inside the Natura 2000 areas 'Lake Gopło', PLH040007, and 'Gopło sanctuary', PLB040004, about 10 km east of the Jóźwin IIB strip mine. For a similar purpose, the study included peatlands in the Forest region around Lake Niedzięgiel (Skorzęcińskie), located 15 km away from the same strip mine. This lake witnessed a noticeable but smaller lowering of water table; nevertheless, it greatly damaged the attractiveness of a large recreational centre located on the lake.

In 1957–1965, in the PLP, there were 146 peatlands (1,169 ha) and 5 gyttja deposits (103.25 ha). By far, small peatlands (<2 ha) dominated (38%), while 10 ha plus ones accounted for only 20% of the total peatland area. Mean peat thickness was only 1.06 m and exceeded 2.0 m only in 18 peatlands [ILNICKI *et al*. 2017]. These were fens for the most part built of sedge and reed peat, more rarely of moss peat, while only a single peatland was classified as transitional. As a rule, they spread over calcareous gyttja, which argues in favour of their development being a result of a gradual shallowing and overgrowing of lakes.

MATERIAL AND METHODS

The effects of deep peatland drainage can be shown by comparing terrain datum's in the past and after the lapse of about 55 years, analyzing the changes in peatland use, and comparing the ash content of the surface layers of organic soils or their total thickness. Unfortunately, the unavailability of peatland levelling results prevented us from determining how much their surface had subsided. Similarly, the unavailability of precise locations of peatland core drilling (with analyses) performed in 1957–1965 by various authors prevented us from making direct comparisons of ash content changes in selected layers of a soil profile. For these reasons, the study attempted to determine ash content changes in the surface layers of 20 selected peatlands and changes in the use of all peatlands over about 55 years. The subsidence of a peatland surface over a long period of time is caused chiefly by the mineralization of peat and moorsh in the surface layers of a soil profile. The change from grasslands to arable land, and tree and bush overgrown land is intensified by peat and moorsh mineralization.

In 1957–1965, in PLP peatlands, 49 core drillings were performed and samples collected for laboratory examination, while in the comparison area 'Skulsk', four drillings were made. Their locations are shown on available maps with a scale of 1:25,000. The samples were examined for ash content, degree of decomposition (in percentages), and peat type, using microscopic analyses. The names of peat types from 1957–1965 did not always correspond to those defined later in Standard PN-G-02500:1985. The degree of peat decomposition was determined then in percentages using van Post's scale. It distinguished poorly decomposed peat (<30% and H1-2, fibric), medium decomposed peat (30–70%, H4-6, hemic) and strongly decomposed peat (>70%, H7-10, sapric). Today, the three named degrees of peat decomposition are used. In the old investigations, moorsh kinds were not studied. Today, three moorsh types are distinguished, with only humus moorsh (MII) and grainy moorsh proper (MIII) having been encountered in 2017. Organic soils ash content is <80%, while that of organomineral soils is 80–90% and of humic soils >90%. In many samples, peat was mixed with calcareous gyttja, making its ash content grow considerably.

To compare the ash content of surface soil layers, 21 peatlands were selected. In the drillings performed there earlier, ash content was determined chiefly at a depth of 30–50 cm, and only rarely at a depth of 10–30 cm. The mineralization of organic mass in drained peatlands takes place mainly in the layer of 0–40 cm, while its intensity depends on the depth of the groundwater level, the moisture content of the surface moorsh and peat layers and peatland use. With the mean groundwater level of 50–70 cm on grasslands, 25 $Mg \cdot ha^{-1}$ is lost per annum [JURCZUK 2011]. With a ditch depth of 0.6–1.0 m and 1.0–1.2 m, peatland surface subsides 0.6 or 1.12 $cm \cdot year^{-1}$, respectively [ILNICKI 1972]. This means that in the roughly 55 years that have passed since the geology of these peatlands was investigated [CZYŻEWSKI 1961; KRASNODĘBSKI 1958; MAREK 1960; PIASECKI 1965; TOŁPA 1960; WĄS 1960], their surface could have subsided by about 33–62 cm. For this reason, a decision was made to collect soil samples for ash content determination from uniform depths of 20–30 cm and 40–50 cm. For this purpose an Eijkelkamp soil auger was used. The following factors were determined: kind of formation, degree of moorsh development or peat decomposition, peat type, and the occurrence of an admixture of sand or calcareous gyttja. Peatlands were numbered following the map of PLP peatlands [ILNICKI *et al*. 2017].

Considering the location of the peatlands in relation to the deepest strip mine, Jóźwin IIB, it was advisable to collect samples of organic soils from the following regions (Fig. 2):
- agricultural (8 drillings), located the closest to Jóźwin IIB and in the vicinity of the trough of lakes Powidzkie-Budzisławskie and Wilczyńskie; peatlands: No. 52 – Grabce, No. 61, 62 and 82 – Budzisław Kościelny, No. 69 – Skrzynka Wielka, No. 83 – Marszewo, No. 84 – Wilczogóra and No. 129 – Szydłowiec;
- forestry (12 drillings) around Lake Niedzięgiel (Skorzęcińskie), located relatively far away (15 km) from Jóźwin IIB, but subject to the negative impact of strip mines; peatlands: No. 11 – Huta Skorzęcka, No. 17 – Smolniki Skorzęckie, No. 19 – Piłka, No. 21 – Skubarczewo, No. 24 and 30 – Wylatkowo, No. 71 – Anastazewo, No. 92 – Słoszewo, No. 94 – Smolniki Powidzkie, No. 97 – Lake Smolnickie, No. 98 – Ostrowo, No. 100 – Hutka;
- comparative area (1 drilling), so far no noticeable impact of the Jóźwin IIB cone of depression has been detected on the trough of lakes surrounding Skulsk, located about 10 km east of Jóźwin IIB; the water level in Lake Skulska Wieś has been regularly measured.

Ash content determinations were performed in the PAN Institute for Agricultural and Forest Environment (Pol. Instytut Środowiska Rolnego i Leśnego Polskiej Akademii Nauk) in Poznań, in compliance with Polish Standard PN-G-04596: Peat and peat production – Determining of ash content. Next, the ash content in the surface layers of the profile of peat-moorsh soils, determined in 1957–1965, was compared with the results of investigations performed in the spring of 2017 (Tab. 2 and 3). The confidence interval was determined for the peat ash content in the agricultural and in the forestry region.

As the type of peatland use has a significant impact on the intensity of peat and moorsh mineralization, information was collected in the field on the way the peatlands were used in 1957–1965, using Google Earth satellite photographs in 2009–2016, and again in the field when collecting soil samples in March 2017. For the first two periods, the changes of the use of all peatlands (1250.2 ha), located within the PLP, are shown (Tab. 4).

Table 2. Comparison of ash content, decomposition degree of peat and moorshing stages of in the periods 1957–1965 and year 2017

Peat-lands number	Period 1957–1965			Year 2017		
	level cm	peat kind, decomposition degree (H) in % and peat land area	ash content %	level cm	kind of peat and moorsh (II–III), decomposition degree of peat (H) acc. to von Post [1924]	ash content %
Agricultural region						
52	50	*Carici-Bryaleti* peat, H 35 – 0.5 ha	12.9	20–30	moorsh III, black, dry	36.47
				40–50	moorsh III, black, dry, grainy	29.70
61	30	*Carici-Alneti* peat, H 75 – 13.0 ha	41.5	20–30	moorsh III, dry, small granulous	65.14
				40–50	moorsh III, black, dry, silted	67.22
62	50	peat mixed with calcareous gyttja – 4.4 ha	62.1	20–30	moorsh III, black, dry, silted	66.11
				40–50	peat H8, black, moist, snail crusts	68.23
69	50	*Carici-Alneti* peat, H 85 – 101.2 ha	63.4	20–30	moorsh III, strongly silted	53.97
				40–50	peat H7, black, moist, snail crusts	88.95
82	50	*Carici-Bryaleti* peat, H 55 – 4.9 ha	44.5	20–30	moorsh III strongly silted	90.68
				40–50	moorsh III with sand, calcareous gyttja	92.08
83	50	*Carici-Alneti* peat, H 50 – 22.8 ha	31.4	20–30	moorsh III, black, strongly silted	82.98
				40–50	moorsh III, black,small granolous,strongly silted	84.30
84	70	*Cariceti* peat, H 40 – 9.2 ha	34.8	20–30	humic sand, many roots	88.77
				40–50	sand with roots	98.55
129	25	*Alneti* peat silted, H 70 – 27.7 ha	49.9	20–30	moorsh III, black, strongly silted (hotel)	74.73
				40–50	calcareous gyttja, dry	96.97
Forestry region						
11	50	*Carici-Bryaleti*, H 28 – 74.0 ha	20.5	20–30	moorsh II, strongly silted	68.86
				40–50	peat H8-9, with calcareous gyttja	94.74
17	50	*Phragmiteti-Alneti* peat, H 36 – 6.0 ha	19.6	20–30	*Cariceti* peat, H6-7	19.82
				40–50	*Cariceti* peat, H5-6	19.87
19	40–50	*Bryaleti* peat, H 36 – 15.0 ha	29.0	20–30	moorsh III, strongly silted	68.78
				40–50	humic sand	90.47
21	50	*Phragmiteti* peat, H 32 – 18.0 ha	22.6	20–30	moorsh II/III, black, grainy, few silted	32.63
				40–50	moorsh I/II, grainy, few silted	26.37
24	50	*Cariceti* peat, H 28 – 15.0 ha	32.9	20–30	moorsh III, strongly silted	78.54
				40–50	moorsh II, silted	38.35
30	50	*Bryaleti* peat, H 12 – 12.0 ha	14.6	20–30	moorsh II, few silted	22.10
				40–50	*Phragmiteti* peat, H5-6, few silted	26.06
71	50	*Alneti* peat, H 85 – 20.6 ha	28.6	20–30	moorsh II, black, few silted	22.67
				40–50	peat H8, black, few silted	22.45
92	50	*Cariceti* peat, H 60 – 34.2 ha	19.3	20–30	humic sand, black, very strongly silted	93.06
				40–50	sand	–
94	50	*Carici-Bryaleti* peat, H 50 – 8.1 ha	42.1	20–30	moorsh III, black, moist, few silted	32.49
				40–50	*Phragmiteti* peat H8, strongly, silted	45.99
97	50	*Carici-Phragmiteti* peat, H 60 – 30.2 ha	32.1	20–30	moorsh III, strongly silted	62.30
				40–50	moorsh III, black, strongly silted	47.56
98	50	*Carici-Alneti* peat, H 50 – 27.1 ha	27.3	20–30	moorsh III, black, moist, with sand,	50.08
				40–50	peat H8, black, with calcareous gyttja	43.72
100	30–50	*Sapric* peat, H 85 – 5.3 ha	39.0	20–30	moorsh II, black, strongly silted	52.12
				40–50	peat H8 with calcareous gyttja	75.52
Comparative region Skulsk						
151	0–10	peat	–	20–30	peat H8, leaving roots	24.21
	10–50	*Carici-Bryaleti* peat, H 35 – 8 ha	20.7	40–50	*Cariceti* peat, H4	14.63

Source: own study.

Table 3. Comparison of ash content (%) in soils of separate peatland regions near the brown coal strip mine Konin in different periods

Region	Number of peat lands	Ash content in 1957–65 in the layer 30–50 cm		Average ash content in the year 2017 in the layer			
				20–30 cm		40–50 cm	
		average	oscillations	average	oscillations	average	oscillations
Agricultural Budzisław Kościelny	8	42.6 ±13.9	12.9–63.4	69.9 ±15.4	36.5–90.7	78.3 ±19.2	29.7–98.6
Forestry Lake Skorzęciński	12	27.3 ±5.3	14.6–42.1	50.3 ±15.5	19.8–93.1	48.3 ±17.1	19.9–4.7
Comparative Skulsk	1	20.7	–	24.2	–	14.6	–

Source: own study.

Table 4. Change of peatland utilisation in the Powidzki Landscape Park between the periods 1958–1965 and 2009–2016

Period	Measure-ment unit	Peatland utilisation					
		grassland	rushes with shrubs	forest	water	arable land	total
Large peatlands (>2 ha)							
1957–1965	ha	712.9	126.0	105.5	242.3	0	1186.7
	%	60.1	10.6	8.9	20.4	0	100.0
2009–2016	ha	252.9	109.8	506.0	182.0	136.0	1186.7
	%	21.3	9.3	42.6	15.3	11.5	100.0
Small peatlands (<2 ha)							
1957–1965	ha	37.8	12.15	5.85	7.75	–	63.5
	%	59.6	19.1	9.20	12.2	–	100.0
2009–2016	ha	12.3	13.0	28.7	4.8	4.7	63.5
	%	19.4	20.5	45.1	7.6	7.4	100.0
All peatlands							
1957–1965	ha	750.7	138.2	111.3	250.0	–	1250.2
	%	60.0	11.1	8.9	20.0	–	100.0
2009–2016	ha	265.2	122.8	534.7	186.8	140.7	1250.2
	%	21.2	9.8	42.8	14.9	11.3	100.0

Source: own study.

RESULTS AND DISCUSSION

The comparison of ash content changes in various layers of 21 peatlands between 1957–1965 and 2017 (about 55 years) is shown in Table 2. In the agricultural region, having been for a long time under the very negative impact of brown coal strip mines exploited between Budzisław Kościelny and Kazimierz Biskupi (Fig. 2), eight peatlands were studied. In the forestry region around Lake Niedzięgiel (Skorzęcińskie), with a smaller negative impact, 12 peatlands were studied, and in the comparative area near Skulsk only one peatland, not influenced by the coal strip mine, was studied (Fig. 2). The locations of bore holes in the peatlands investigated in the two periods were not exactly the same, but all results together give a good picture of the trend in peatland disappearance. The area of investigated peatlands changed between 0.5 and 101.2 ha (Tab. 2), mostly between 5 and 30 ha.

In the agricultural region (Fig. 2) located the closest to brown coal strip mines, in the period of 1957–1965, in the 30–50 cm layer, *Cariceti-Alneti*, *Cariceti* and *Alneti* peat dominated, mostly of the hemic and sapric decomposition degree and with a high (30–60%) ash content. Only one small peatland (No. 52 in Grabce) is the deposit of *Cariceti-Bryaleti* peat with a low ash content and fibric decomposition degree (Tab. 2). In 2017, peat layers can be found only in two peatlands (Pos. 62 and 69), at a depth of 40–50 cm. In the 20–30 and 40–50 cm layers, mostly grainy moorsh (MIII) is found with a very large admixture of sand; in peatland No. 84, it has already changed into humic sand on sand. In peatland No. 129, moorsh borders directly on calcareous gyttja, while in peatland No. 82, its deeper layer is mixed with calcareous gyttja. In peatland No. 69, the peat layer (40–50 cm) has a very high ash content, owing to an admixture of snail shells that used to live in a lake that once been there. These changes illustrating peatland disappearance are shown in Fig. 3. An overall comparison of ash content changes in all the examined samples from the peatlands in this region reveals that in the peat layer, at a depth of 30–50 cm, the mean ash content 55 year ago was 42.6% while in 2017, in has grown to 69.9% in the 20–30 cm layer and 78.3% in the 40–50 cm layer (Tab. 3). Thus, the ash content of the over dried organic soil layer has grown over 55 years by almost 30%. The shallowing of organic soils makes moorsh mix with underlying calcareous gyttja and sand, resulting in the ash content exceeding 80% already in a half of examined soil samples. This means a change of organic soils into mineral ones, with the process being the most intensive in peatlands nos. 82, 83, 84 and 129 located in the vicinity of Budzisławskie and Wilczyńskie lakes, i.e. the closest to the deepest and currently exploited strip mine, Jóźwin IIB.

In the forestry region (Fig. 2), in 1957–1965, in the 30–50 cm layer, there was always peat in all its basic fen types: *Bryaleti* and *Carici-Bryaleti* (4 peatlands), *Cariceti*, *Carici-Phragmiteti* and *Carici-Alneti* (4 peatlands) as well as *Phragmiteti* (2 peatlands) and *Alneti* (1 peatland).There also occurred sapric peat, lacking any remains of peat-producing plants (peat-

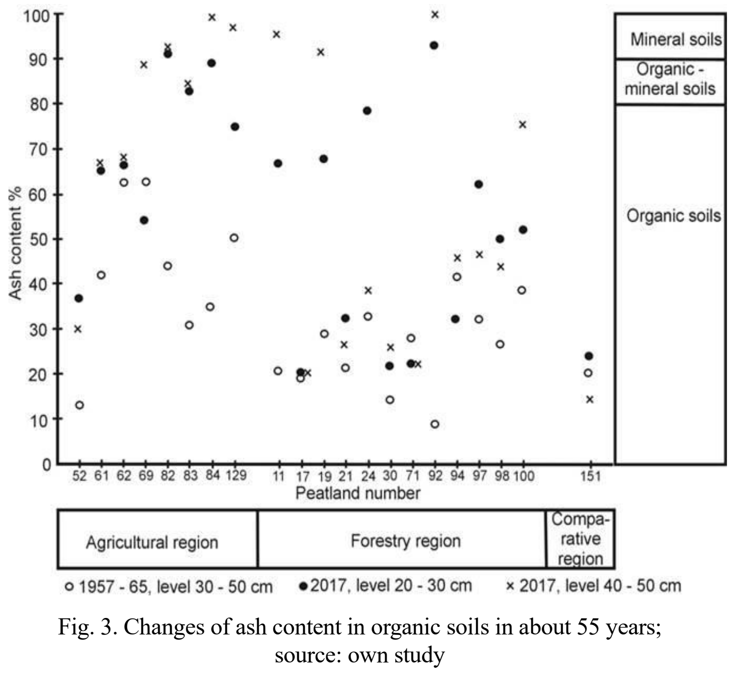

Fig. 3. Changes of ash content in organic soils in about 55 years; source: own study

land 100). Peat types with bryophytes showed in most cases a low and medium decomposition degree and a very varied but clearly higher (14.6–42.1%) ash content. Peat types with predominance of sedge remains (*Cariceti*) showed a medium and high decomposition degree and a higher ash content (approx. 30%). Peat kinds with predominance of reed remains (*Phragmiteti*, *Phragmiteti-Alneti*) were decomposed to a medium degree (hemic) while their ash content stayed around 20%. In peatland No. 100, there was highly decomposed (sapric) peat with a high ash content (39%).

In 2017, sedge peat (Cariceti) is found in the entire 20–50 cm layer only in peatland No. 17, on overgrown inland Lake Czarne, being the only habitat management area in the PLP. In the 40–0 cm layer, medium and highly decomposed *Phragmiteti* peat is found only in peatlands No. 30 and 94 in Wylatkowo and Smolniki Powidzkie. In peatlands Nos. 11, 71, 98 and 100, in the deeper 40–50 cm layer, peat of a very high decomposition degree is still found. In peatland No. 71, this is *Phragmiteti* peat of a higher ash content (22%). In the other three peatlands (11, 98, 100), peat with a high admixture of calcareous gyttja occurs, which is seen in a very high ash content (44–95%). Peatlands Nos. 11, 71, 98 and 100 are located in the watershed part of the trough, joining lakes Powidzkie and Budzisławskie, while peatland No. 11 lies in Huta Skorzęcka, on the west shore of Lake Powidzkie, where it is underlain and protected against water sinking by a thick (2.6 m) layer of impermeable calcareous gyttja. In all the other peatlands, in the more shallow layers of the above-named natural features, only humic (MII) or grainy (MIII) moorsh is found now. In peatlands No. 21 (Skubarczewo, at the source of the Noteć Zachodnia), No. 24 (Zielątkowo) and 97 (on Lake Smolnickie) humic moorsh is found also in the deeper layer (40–50 cm). Various types of moorsh are characterized as a rule by a high ash content – about 50% (Tab. 3), but noticeably lower than in moorsh types on farmland (about 70%). In the 40–50 cm layer of peatlands No. 19 (Piłka) and No. 92 (Słoszewo), instead of peat, humic sand and sand were found, indicating an already well-advanced process of peat disappearance. In the entire woodland studied, the mean ash content in the 20–50 cm layers stays around 50%. In peatlands Nos. 11, 19 and 92, it exceeds 90%, indicating the final stage of peatland disappearance or resulting from a high content of calcareous gyttja in peat (No. 11). This is largely an effect of the deep drainage of the brown coal mines Kazi-mierz Południe, Kazimierz Północ and Jóźwin IIA, operating since 1962, and especially of the much deeper and closer to peatlands Jóźwin IIB.

In the comparative region "Skulsk", which is located outside the impact range of the actual declared cone of depression of strip mines, a peatland located on Lake Skulska Wieś was studied. In this lake, the water level has not changed for several decades. In 1960, in the peatland, at a depth of 10–50 cm, *Carici-Bryaleti* peat was found, characterized by a medium degree of decomposition and an ash content of 20.7% [WĄS 1960]. In 2017, in the 20–50 cm layer, sedge peat was indentified, displaying a medium degree of decomposition and showing an ash content of 14.6%. In the waterlogged peatland, moorsh has not developed, but the surface layer (20–30 cm) shows a peat with much greater degree of decomposition and a slightly higher ash content (24%). There are no signs of peatland disappearance although the peat was be heavily exploited there for fuel.

Changes in peatland use have a significant impact on the intensity of peat and moorsh mineralization. The process is accelerated by the lowering of the groundwater level. With deeper drainage, grasslands are changed into arable land and woodland. When meadows and pastures are no longer used, reed rushes appear on them and they are overgrown with bushes and trees. Since this type of vegetation uses more water, it intensifies the lowering of the level of shallow groundwater, thus, accelerating the mineralization of the organic substance of the soil. For this reason, peatland use in 1957–1965 and 2009–2016 was compared (Tab. 4).

Changes of peatland use may have economic reasons such as peat exploitation for fuel during economic crises and wars, the effects of which in Table 4 are shown in column 'water', covering both old peat pits and peat pits turned into fish ponds. Another reason has to do with a higher economic profitability of field production when compared to meadow and pasture production; its effects are shown in column 'arable land'. When grasslands completely stop to be used, they are replaced by rushes with many shrubs and woodland. These processes depend to a high degree on peatland size and location with respect to the house of the owner of land. For these reasons, peatlands below 2 ha were treated differently than larger ones. There are 63.5 ha of the former in the PLP and 1,186.7 ha of the latter. In both peatland groups, the direction of peatland use changes is similar. The confidence interval indicates a greater increase of the peat ash content differentiation in the agricultural than in the forestry region.

In the case of large peatlands, over 55 years, the share of grasslands has dropped from 60.1% to 21.3%, while the shares of woodland (from 8.9 to 42.6%) and arable land (from 0 to 11.5%) have grown considerably. In contrast, the share of open waters has dropped (from 20.4 to 15.3%) as has, albeit marginally, the share of rushes with shrubs (from 10.6 to 9.3%). In peatlands below 2 ha in size, the share of grasslands has fallen about threefold, with the share of woodland growing considerably (from 9.2 to 45.1%) and arable land accounting for 7.4%. In small peatlands, the share of open waters has dropped slightly (overgrowing peat pits), while the share of rushes has not changed significantly (about 20%). The most significant changes in all peatlands are a threefold fall in the share of grasslands (to about 20%), emergence of arable land covering already 11.3% of peatland area, and almost a fivefold growth in the share of woodland. The fall in the share of grassland, once a predominant form of peatland use, is a clear indication of the 'drying-up' of peatlands.

Until now, no studies of peatland disappearance have been made; studies have focused solely on determining the extent of peatland subsidence [ILNICKI, SZAJDAK 2016]. In the vicinity of brown coal strip mines or large groundwater intakes, one could expect a much more intensive process of peatland disappearance. Studies of this kind are difficult and call for collecting much data from various fields. Frequently, it is hard to come by. Nonetheless, it is necessary to draw the attention of the public opinion to gradual peatland disappearance observable throughout Poland. In many regions, peatlands are the most fertile soils available for cultivation. At present, the process under discussion escapes the attention of farmers, institutions and environment protection agencies of all levels. Failure to take some measures to curb the process of peatland disappearance, in particular of shallow peatlands, will result in a drastic reduction of peatland areas in Poland in the future

CONCLUSIONS

The technical capacity of small hydropower plants that could be built on the 4 weirs existing on Tyśmienica River is 0.131 MW. These power plants could produce 786 MWh of electricity per year. It is difficult to assess the economic effectiveness of this production at present, as currently a new support system for renewable energy is being implemented in Poland, in the form of an auction system. The economic result will be the most important factor for investment decision making by entrepreneurs. Formal and legal requirements of the investment are also important. The tested weirs are located in protected areas within the Natura 2000 network, which may limit their construction. The obligation to carry out an environmental impact or Natura 2000 network impact assessment is subject to certain costs, more stringent requirements and a complex procedure. However, location of a small hydropower plant in the area covered by some forms of protection is possible, especially in the case of solutions with the least possible environmental impact.

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Przyśpieszone zanikanie torfowisk w sąsiedztwie Kopalni Odkrywkowej Węgla Brunatnego Konin

STRESZCZENIE

W Powidzkim Parku Krajobrazowym znajduje się 150 torfowisk o obszarze 1250,2 ha. Na jego obrzeżu prowadzona jest odkrywkowa eksploatacja węgla brunatnego powiązana z głębokim odwodnieniem terenu. Spowodowała ona drastyczne obniżenie lustra wody (do 5,0 m) w istniejących tu jeziorach i przyśpieszyła proces zanikania torfowisk. W celu ustalenia jego zakresu porównano określone w latach 1957–1965 i w 2017 r. rodzaje i popielność powierzchniowych warstw gleby w 20 torfowiskach. Leżą one najbliżej odkrywki Jóźwin IIB położonym regionie rolniczym i w dalej położonym regionie leśnym. Wyniki porównano z torfowiskiem w Skulsku, na które kopalnia negatywnie nie oddziałuje. Występujące ok. 55 lat temu torfy niskie w większości przekształciły się w mursz ziarnisty. W warstwie 20–50 cm nastąpił blisko dwukrotny wzrost popielności, a w części torfowisk gleby organiczne przekształciły się w gleby mineralne i organiczno-mineralne. Największe zmiany wystąpiły w regionie rolniczym. We wszystkich torfowiskach na terenie Parku trzykrotnie zmalał obszar użytków zielonych i pięciokrotnie wzrosła powierzchnia lasów. Obecnie 10% ich powierzchni zajmują grunty orne, których uprzednio nie było wcale.

Słowa kluczowe: *degradacja jezior, kopalnia odkrywkowa węgla brunatnego, obszar Natura 2000, park krajobrazowy, zanikanie torfowisk, zmiana użytkowania torfowisk*