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The Effect of Adjustable Outflow on the Fluctuations in the Level of Surface and Ground Water

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ABSTRACT
This paper aims to analyze the variability of the surface and ground water levels in Ambona peatlands. The depth at which the ground water table occurred was studied with reference to the adopted land drainage standards. The studies were carried out in 2009/10–2015/16 for natural and regulated water outflows. The analysis of annual total precipitation suggests that in the analyzed period some years were very wet (2009/10 and 2013/14), some were wet (2010/11, 2012/13 and 2015/16), one year was dry (2014/15) and one year was normal (2011/12). The 7-year average seasonal precipitation amounted to 598 mm, which was 71 mm higher than the average precipitation recorded in 30 years. The level of water in the river under adjustable outflow conditions ranged from 55 to 77 cm. The level of water under natural outflow ranged from 18 to 49 cm. In the area with adjustable outflow, the average draining depth was 47 cm. In the remaining area, not covered by the irrigation system, the draining depth was 64 cm. Additionally, the dynamics of variance in the water level under natural outflow conditions was clearly higher.

Keywords: adjustable outflow, precipitation, surface water, ground water

INTRODUCTION

Water protection is comprehensively regulated by the Water Framework Directive (2000/60/EC), the main goal of which is ensuring good quality of water by 2015. In Poland, water protection takes on a special significance because it is a country with very poor water resources [Chełmicki 2002]. Water deficit imposes limitations on the possibility of economic development and necessitates a thorough analysis of risks [Mioduszewski 2012, 2014]. Polesie Lubelskie is an area with 1st class rainwater storage needs. Availability of water in the specific amount, quality and time is an essential element of sustainable economic development [Chmielewski (ed.) 2000].

Water and natural factors determine the environment. In addition, certain adverse effects connected with water occur on the Earth. These include droughts and floods. Apart from the spatial variation in the distribution of precipitation, we also deal with its variability in particular years and seasons [Xoplaki et al. 2004; Bajkiewicz-Grabowska, Mikulski 2006; Chmielewski, Sławiński 2009].

The identification of the hydromorphological status of surface water should involve a description of changes in the outflow regime [Brandyk 2002]. Such changes are measured as the ratio of average flow under regulated conditions to average flow under natural conditions. The information on water resources includes characteristic water levels and flows in particular months.

This paper aims to analyze the variability of the levels of surface and ground water in peatlands. The depth at which the ground water table occurred was studied with reference to the adopted land drainage standards. The studies were carried out in 2009/10–2015/16 for natural and regulated water outflows.

MATERIAL AND METHODS

Since October 1999, the Department of Environment Management and Geodesy Engineering at the University of Life Sciences in Lublin has carried out comprehensive studies of water resources in the catchment area of the Ochożanka river. The studies mainly involve: measurements of daily water levels in the closing section, monthly flow rates and periodic measurements of geometric parameters of streams. The measurements are performed both in the Ochożanka river and in drainage ditches in the peatlands.

This paper presents the results of hydrological measurements carried out in 2009/10–2015/16. The tests were performed in alder peatlands Ambona extending over an area of 181 ha in hydrometric sections (Fig. 1). Hydrological observations included:

- Measurement of surface water levels in the river and ditches,
- Measurement of the depth at which the ground water table occurred in piezometers,
- Maintenance processes.

The weather conditions in the catchment area were determined based on the data provided by the agrometeorological station in Sosnowica. Digital data recorders were used for the purpose of hydrological and meteorological measurements.

Western Polesie, according to the division of Poland into climatic zones (Romer), is located within the climatic area of the Great Valleys in the Chełm-Podlasie region. The region is characterized by high annual temperature amplitude reaching 23.5°C and the average total annual rainfall of 560 mm. According to the classification of agricultural regions (Gumiński), the analyzed area is situated at the border of District IX – Eastern and District XIII – Chełm. The number of snow cover days is 80 and that of ground frost days – 132. In terms of the climatic regions classification, this area is situated in the Mazovia-Podlasie region where summer starts early [Chmielewski, Sławiński 2009]. As far as climatic zones classification is concerned [Kaszewski 2008], this area is situated in Polesie Region which is characterized by very low climate variability.

RESULTS

The studies were carried out over 7 hydrological years in the Ambona peatland under variable precipitation conditions. It provided an opportunity for objective evaluation of the drainage system operation. The analysis of annual total precipitation suggests that in the analyzed period, some years were very wet (2009/10 and 2013/14), some were wet (2010/11, 2012/13 and 2015/16), one year was dry (2014/15) and one year was normal (2011/12) [Miętus et al. 2005]. The 7-year average seasonal precipitation amounted to 598 mm (Table 1), which was 71 mm higher than average precipitation recorded in 30 years [Grzywna et al. 2016b]. In the winter hydrological half-year, the highest precipitation was recorded in 2013/14 – 193 mm, while the lowest in 2009/10 – 134 mm. Precipitation was considerably more varied in the summer half. It ranged from 262 mm in 2014/15 to 541 mm in 2009/10 (51% higher than the multi-year average). Precipitation distribution throughout a year was uneven and it ranged from 30 mm in December to 96 mm in May, on average. In the studied period, the heaviest precipitation was recorded in July 2011 – 242 mm, while

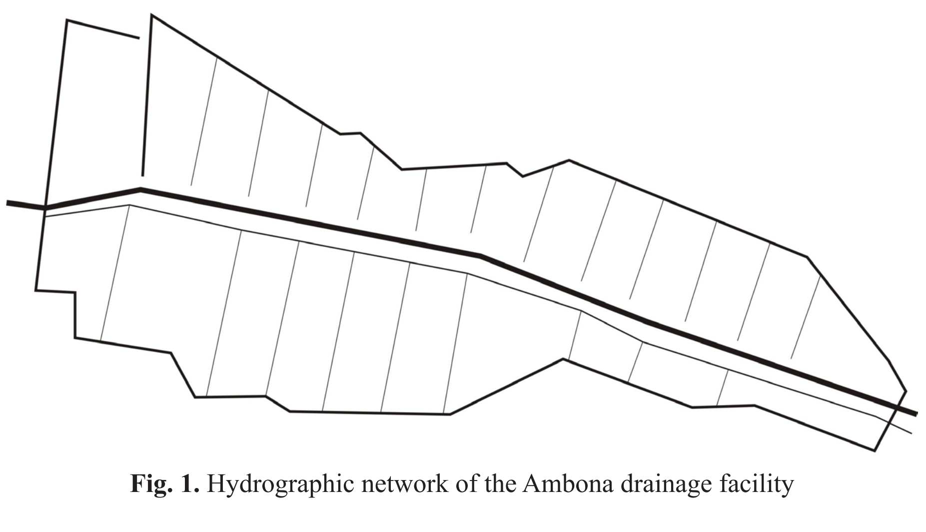

Fig. 1. Hydrographic network of the Ambona drainage facility

Table 1. Periodic precipitation totals [mm]

Year	XI-IV		V-X		XI-X	
	mm	Classification	mm	Classification	mm	Classification
2009/10	134	dry	541	extremely wet	675	very wet
2010/11	167	normal	486	very wet	653	wet
2011/12	148	dry	373	normal	521	normal
2012/13	189	wet	416	wet	605	wet
2013/14	193	wet	490	very wet	683	very wet
2014/15	205	wet	262	very dry	467	dry
2015/16	275	extremely wet	335	normal	610	wet
Average	187	normal	411	wet	598	wet
1985–2014	169	normal	358	normal	527	normal

the lowest amount was noted down in November 2011 and February 2015 – 2 mm (Figure 2).

The normally positive water balance in the winter season and the negative one in the summer season indicate the need for a very early storage of rainwater in the natural environment. Field studies carried out under different water supply conditions revealed very poor water resources. Therefore, a regulated outflow irrigation system had to be applied [Pokładek, Nyc 2007; Nyc, Pokładek 2011].

Thanks to all-year-round regulation of the outflows, the ground water level stopped decreasing. The operation of dams increased the stability of surface and ground water levels. Under the regulated outflow conditions the variance in surface water levels remained below 22 cm. The coefficient of variation of mean monthly water levels was only 6%. The level of water in the river ranged from 55 to 77 cm, given the depth of 120 cm (Figure 3). The highest average water levels were recorded in March, whereas the lowest ones in August._The average water level of the multiyear was 70 cm. For ground water levels, the variance did not exceed 37 cm. In the vegetation period, the average meadow draining depth within the range of the dam was 47 cm. Land draining depth ranged from 28 cm at the beginning of the vegetation period to 65 cm at the end of that period. The acceptable maximum draining standard for the analyzed alder peatlands is 60 cm [Szajda 2009]. Under the regulated outflow conditions, the ground water level decreased excessively only in 2012. Although the precipitation levels in particular years were differentiated, the surface and ground water levels were successfully stabilized. Thanks to all-year-round regulation of the outflows, the ground water level stopped decreasing and the consequences of excessive dryness in the vegetation period could be prevented.

In the analogous period, at checkpoints located outside the dam impact zone, the variance in surface water levels amounted to 31 cm. The coefficient of variation of mean monthly water levels was 13%. The level of water in the river ranged from 18 to 49 cm, given 115 cm depth of the river bed. The highest average water levels were recorded in March, whereas the lowest

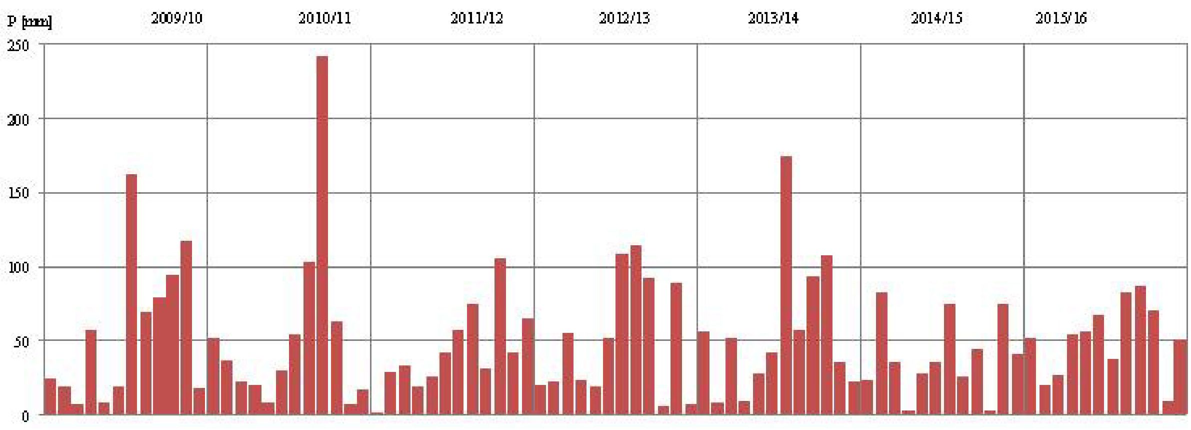

Fig. 2. Monthly rainfall in 2009/10 and 2015/16 years

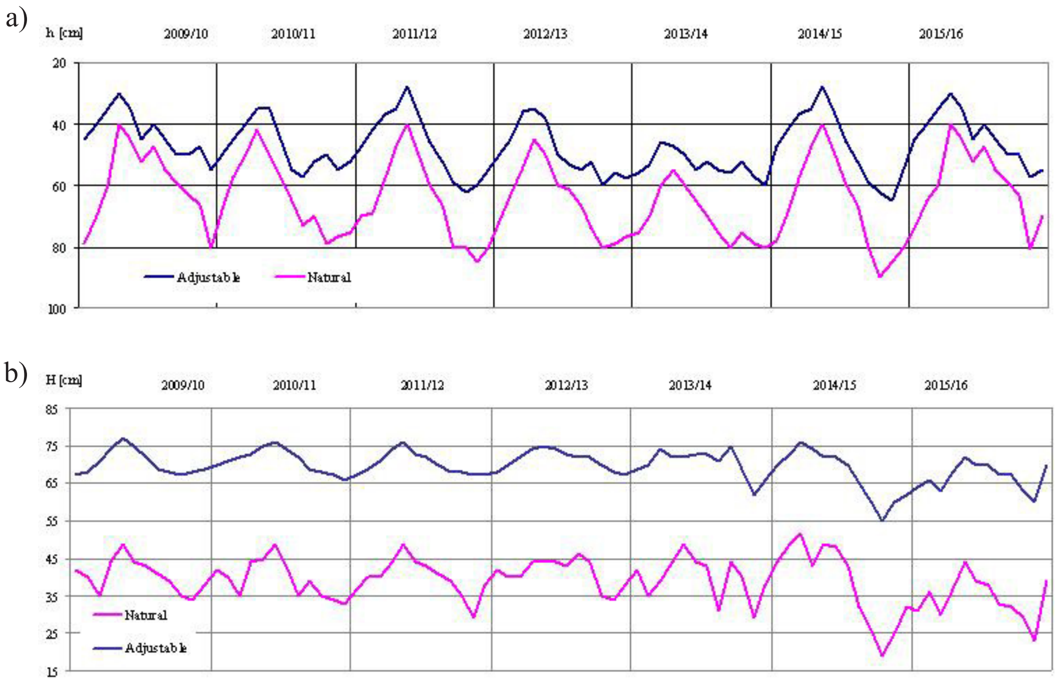

Fig. 3. Monthly average of ground water depth and surface water levels

ones in September. The average water level of the multi-year was 49 cm and 21 cm was lower than the regulated outflow. In the vegetation period, the variance in ground water levels reached 64 cm. Land draining depth ranged from 40 cm in March to 90 cm in August 2015 (Figure 3). Under the natural outflow conditions, the ground water level decreased at the beginning of June. Similarly to the checkpoints located within the dam impact zone, the highest reduction in the level of water was recorded in 2015. In 2012 and 2013 soil drought occurred at non-irrigated checkpoints. In the remaining years, despite high total rainfall, the water level was also excessively reduced. Even in very dry vegetation periods in 2014 and 2016, a hydrological drought occurred.

Groundwater levels are also characterized by spatial variability [Kumar, Remadei 2006; Grzywna et al. 2016a; Bhadra et al. 2018]. The lowest values of depth at which the ground water level was found were normally recorded in the centre of the meadow section. The lowest level of ground water was recorded near the drainage ditch (out of the range of the dam). In dry year 2015 soil drought occurred at all checkpoints.

The dynamics of ground water levels in the analyzed Ambona peatlands was similar under the natural and regulated outflow conditions and it was mainly determined by the impact of weather conditions. The analysis of trends related to changes in surface and ground water levels in time consisted of testing the zero regression slope hypothesis [Murat-Błażejewska et al. 2005]. According to the analysis, the tested hypothesis was found statistically significant in the river and in piezometric wells.

A correlation analysis was carried out in order to determine the relationship between the surface water levels in the river and ground water levels. The tests revealed a statistically significant relationship (level of significance α=0.05) between the surface and ground water levels. The results indicate that the strongest relationship exists between the level of water in the river and the level of water in the centre of the meadow section ($r^2 = 0.54$). The relationship between water levels points to a strong hydraulic bond between the surface waters and shallow underground waters that are characterized by a similar dynamics of changes, mainly determined by the weather conditions.

CONCLUSIONS

1. In small agricultural catchment areas with very limited water resources, outflow should be regulated to prevent hydrological and soil drought.
2. As a result of all-year-round regulation of water in a stream, the effects of maintaining large resources of stored water were very good. The average water level of the multi-year was 39 cm and 31 cm was lower than the regulated drain.

3. In the area with regulated outflow the average draining depth was 47 cm. In the remaining area, not covered by the irrigation system, the draining depth was 64 cm. Additionally, the dynamics of variance in the water level under natural outflow conditions was clearly higher.
4. The effect of an irrigation system with regulated outflow on the levels of surface and ground water depends on correct agricultural management, operating processes related to the use and maintenance of the irrigation system and the level and distribution of rainfall.

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