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THE GROUNDWATER LEVEL CHANGES CAUSED BY MODERNIZATION OF WATER DEVICES IN THE POMORZE FOREST DISTRICT

Michał Wróbel [1]***, Andrzej Boczoń*** [1]***, Sylwester Grajewski*** [2]***,***
Anna Krysztofiak-Kaniewska[2]
Forest Research Institute in Sękocin Stary ,[1]*Poznań University of Life Sciences* [2]

Abstract

Because of more and more frequent droughts and observed climate changes, infrastructural investments in forest are at present targeted at increasing water resources, which is realized under the so-called small-scale water retention. Forest reservoirs located in Pomorze Forest District in the north-eastern Poland, which was selected for research, fits this trend. The constructed facilities were to reduce the indications of habitat dryness and to improve fire prevention. The investment consisting in building 14 objects of water melioration has changed water conditions in the research area. 12 oak dams, stone weir and an earth pond for amphibians have been built. As a result of the realized investment, the level of water has increased and problems with periodical flooding of forest habitats have occurred. At the beginning of 2012, observational and measuring wells were created to monitor all occurring changes of the soil water table. The received data can be useful in clarifying the causes for flooding and in possible suggestions to improve the existing water conditions. This paper presents the analysis of the influence of realized investments on the changes in the level of groundwater between 2012 and 2014.

Key words: small-scale water retention, groundwater.

INTRODUCTION

Water conditions are among major factors deciding about a sustainable development of young tree stands which is possible only if changes in water conditions are relatively small. Changes which exceed tree tolerance to lack or excess of water are a threat to forests.

The identified trends, namely a decrease in soil water table in various habitats (Miler et al., 2015, Pierzgalski et al., 2002, Frydel and Miler, 2014; Boczoń, Wróbel 2015), enforce implementation of measures preventing that phenomenon. Taking action under small-scale water retention, which has already assumed its proper place in forest management, is to create the right conditions for the development of tree stands. Because of its influence on and importance to the state of the forest, the role of small-scale water retention should be strengthened and be priority, enabling a sustainable development of forest ecosystems (Zabrocka-Kostrubiec, 2008; Miler 2015). Taking into consideration the diversity of forest habitats and the need to maintain stable moisture conditions for long-lived tree stands, it should be stated that any projects of undertakings aiming to correct the natural water cycle in forests have to consider multiannual effects of planned actions. It is also necessary to optimize the control of water resources accumulated in the reservoirs and the hydrographic network (Kędziora et al., 2014; Pierzgalski, 2015). The following factors have to be subjected to thorough evaluation in project work and decisions to be made: the size of the reservoir area, the impact of dams on groundwater, the impact of other reservoirs on water ecosystems, ecological changes caused by banked up or retention water. Each projects has to take into account the specificity of forest ecosystem and be subjected to investment impact assessment, both positive and negative.

Drainage in Pomorze Forest District (which have mostly drain function) were built in the 1960s. Between 1980-1992 was a rather dry period, which resulted in signs of dryness and decrease of tree fitness. In order to improve water conditions and fire protection and to improve biological diversity, small-scale water retention devices projects were prepared in 2006 and implemented between 2007-2010. 53 retention constructions were built in 7 facilities indicated by Forest District. In case of the facility which is being investigated 14 of those constructions were built, namely 12 oak dams, a stone weir and an earth pond for amphibians. Once the investment was completed, problems with too high level of water table occurred periodically, as a result of which the adjacent terrain was flooded. This paper presents the analysis of the influence of realized investments on the changes in the level of groundwater after the implementation of investment related to small-scale water retention.

MATERIAL AND METHODS

The Pomorze Forest District, where the research subject is located, is in the north-eastern Poland. In order to determine the influence of small-scale water retention facilities on changes in water conditions, meteorological reconnaissance, land surveying and an assessment of existing drainage facilities had to be carried out. Forest Research Institute performs measurements of meteorological parameters in Żyliny. The station is located around 11 km away from investigated small-scale water retention facilities, which exerts influence on a rather good illustration of changing meteorological conditions in the investigated facility.

In order to describe elements of drainage system as well as asses the role of drainage facilities in tree stand flooding, land surveying by means of total station NIKON type and GPS EPOCH 25 receiver.

The investigated facilities comprise regular drainage ditches system of a total length of approximately 4000 m. The drainage ditches system was made on a flat terrain of small land slopes. First the main ditch r3 was a tributary of ditch r1. However, ditch r3 is not connected to ditch r1 (fig. 1). Therefore, it has to be treated as a contained one. 13 dams of wood-earth construction, each of damming height of 0,65 m and frame width of 3 m. What is more, a pond for amphibians of 1000 m^2 area and a stone weir of damming height of 0.7 m.

The condition of infrastructure of the facility shows that dams generally are in a good condition. No damage or leakage was found. Their upper part is covered with vegetation and uncovering it shows that the wooden construction is with no significant damage. Sand pack and rip-rap are also in good conditions and no significant damage was found. The construction seems solid and resistant to mechanical damage. In comparison to dams, the conditions of ditches is worse. Over the entire length of ditches running on the boundary between forest and meadow (ditch r3 between wells st.1 and st.2), heavy scrub encroachment and their local shallowing has been observed. This results in a significant reduction of the possibility of water flow in these sections. Those ditches are characterized by a high depth variability which is from a few to several centimeters. Clear ditch channels are found in wooden land where dams are also found (fig. 1).

In order to recognize changes in water conditions in the investigated areas, three observational and measuring wells with automatic data recording have been created. Measurements of changes in the level of soil water table were started on April 14, 2012.

RESULTS

As is known, a characteristic feature of basic factors deciding about water resources, i.e. precipitation and air temperature is their variability, both in short and multiannual periods. That is why an analysis of impacts of functioning of constructed retention facilities should include meteorological conditions.

Figure 1. The location of measurement wells (•), and retention objects on the facilities (•).

In the multiyear period of 1982-2014, the average sum of atmospheric precipitation amounted to 639,6 mm. In hydrological years, which better illustrate seasonal variability throughout the year, it can be observed that the highest precipitation occurred in 2013, when it reached a value of more than 685 mm (table 1), which constitutes an average year. The remaining hydrological years were described as dry or very dry.

Table 1. Precipitation [mm] in the hydrological years from meteorological station Żyliny.

Hydrologic year	2010	2011	2012	2013	2014
Precipitation (mm)	543,2	489,3	461,2	685,1	501,4

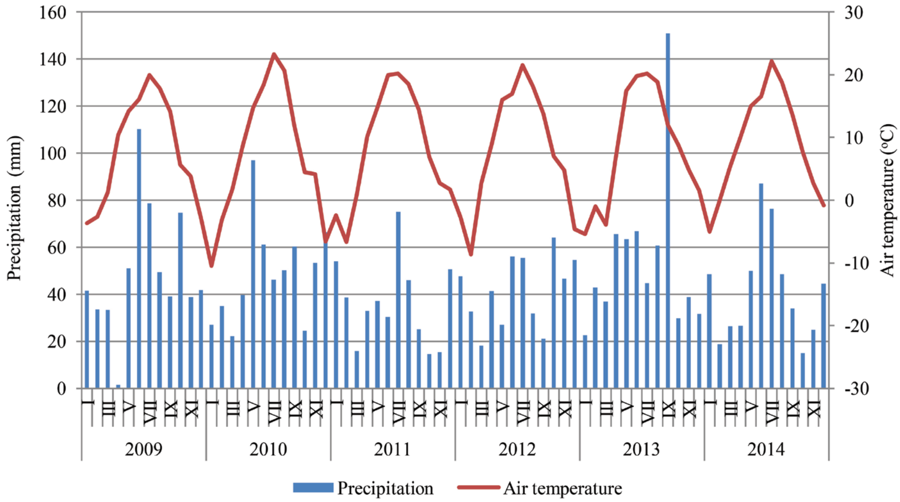

Figure 2. Monthly rainfall and average air temperature in 2009-2014 at the station Żyliny.

The cause for flooding of area adjacent to modernized retention facilities at the beginning of 2011 were surely meteorological conditions and carried out modernization of dams, which slowed down drainage of water. An analysis of precipitation and temperature data has shown that between November 2010 and February 2011 more that there was more than 210 mm of precipitation in this period, which from November included snow. According to average daily values of air temperature from Żyliny station, melting of snow began in the first half of April. Rapid rise in air temperature caused melting of snow, which resulted in flooding. A confirmation of these considerations is also an occurrence of a similar situation at the turn of 2012 and 2013. Over the period from November 2012 to February 2013 (fig. 2). There was almost 170 mm of precipitation and snowmelts began in March/April. As a result of melting of snow, there was a sudden rise in ground water level (fig. 3). In the bottom part of this period, the rise was almost 100 cm, approximately 40 cm in the intermediate and almost 10 cm in the top part respectively. What is more, there was precipitation of 15 mm in September. Soaked with water soil was unable to absorb such amount of water, which resulted in another flooding. According to measurement provided by measuring wells, in the bottom part of the facility this condition lasted until May 2014.

When evaluating the course of changes in water table (fig. 3) it can be concluded that trends in change in water tables in all wells were similar. There were differences in values of rise in water table, but the directions of changes were the same. Well no. 3, which is in the upper part of ditch system, is characterized by the highest level of water table. In its case, water table ranged from 6,6 cm do – 34,2 cm below the ground level. Well no. 2, located near the inlet of side ditch to the main ditch, is characterize d by an amplitude of changes of 77,8 cm and the level of water table ranged from 3 cm to – 74,8 cm below the ground level. Well no. 1, which is in the end part of the system, showed changes which resulted from influx of water from the whole drainage system. The highest amplitude of changes in the level of water table, amounting to 134,1 cm, was observed there. The level of water table itself ranged from 25 cm to – 109,1 cm below the ground level.

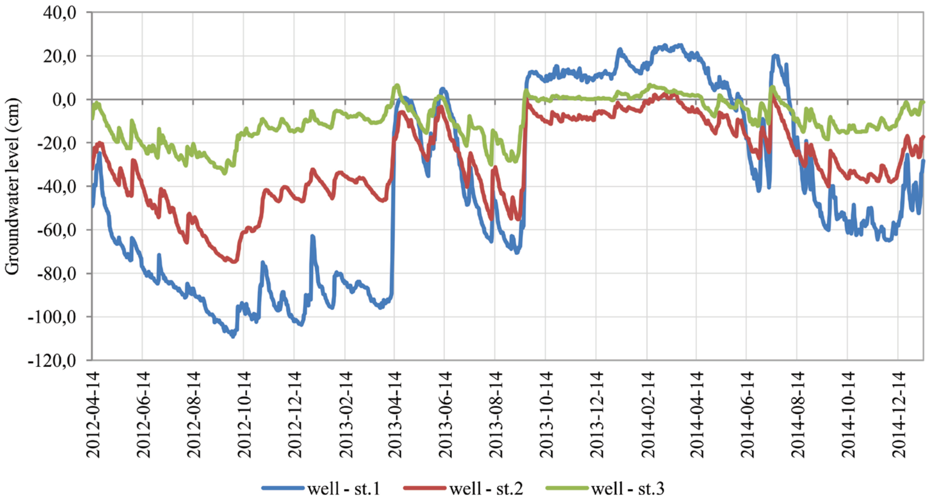

Figure 3. Changes of water level in measuring wells.

DISCUSSION

In 1998 in Augustów, during a seminar on hydrographic conditions in Augustów Primeval Forest it was concluded that it was necessary to take actions aiming to reconstruct retention of hydrogenic soils, increase surface impoundment and constant conservation of water resources of especially important natural sites. Therefore, the undertakings realized in Pomorze Forest District constitute implementation of the above mentioned quotation. However, as early as in the first years after the construction of retention facilities, problems with too high level of water table, which resulted in flooding of nearby tree stands, were observed. One may point to the possibility of control of outflow, but in general small-scale water retention belongs to the so-called uncontrolled retention (Mioduszewski 2002). It is up to the designer and contractor whether a particular facility will really function in a manner which does not threaten the environment. In the investigated area outflow of water is so large during precipitation higher than average that damming on rock steps and sluices reaches the level of overflow. Short-lasting floodings are of course desired, but it should be taken to ensure that the overflow area does not threaten nature in the area. The research carried out in Białowieża Forest has shown that a stable high level of water table causes decrease of growth rings of trees and their dieback within 2 years (Boczoń, Wróbel, Siniayev 2009), which is not desirable in forest areas since a significant damage to tree stands can cause an increase of erosion or outflow (Tyszka 2008). Such a situation must not be allowed and, as a result, depending on aims one wants to achieve, various actions have to be suggested in the investigated area. In case of continuation of production, the condition of retention facilities maybe should be modernized since in years with substantial snow cover and its rapid melting and high precipitation, situations similar to those of 2011, 2013 and 2014 may occur again. A workaround in a form of ditches near the facility, whose level of bottom will be equal to a particular site, or a dam in the retention facility in a form of pipe with a valve can be made. It is also important to create conditions to drain water from the bottom part of the facility.

However, if a decision to reconstruct hydrogenic sites and communities and species related to it is made, it may be necessary to maintain water conditions which encourage peat formation and produce swamp conditions to preserve or restore the natural state of swamp habitats in the investigated facility. An improvement of water conditions by means of swamp formation process will lead to a restoration of natural state of swamp habitats, namely it will restore its typical species composition, structure and functions.

CONCLUSIONS

1. The results indicate the necessity for adjustable weir whenever there is need to protect forests from flooding.
2. A numerical model is proposed to assess the impact of the designed weir on the adjacent land in the process of location of the construction.

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Mgr inż. Michał Wróbel
Forest Research Institute
Department of Forest Ecology
M.Wrobel@ibles.waw.pl

Dr inż. Andrzej Boczoń
Forest Research Institute
Department of Forest Ecology

Dr inż. Sylwester Grajewski
Poznań University of Life Sciences
Department of Forest Engineering

Dr inż. Anna Krysztofiak-Kaniewska
Poznań University of Life Sciences
Department of Forest Engineering
annakrysztofiak@wp.pl

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