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HYDROLOGICAL BASIS OF POSSIBLE WATER MANAGEMENT MEASURES FOR ENHANCING DROUGHT RESILIENCE

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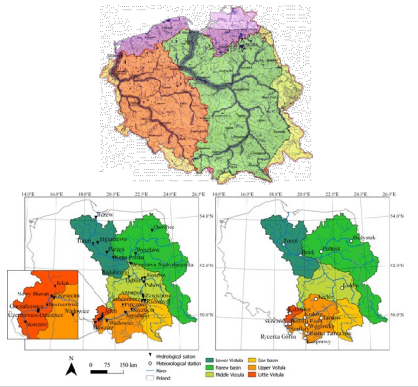
Abstract

The global warming and resulting climatic changes has altered the hydrological regime of Polish rivers especially in winter season. Precipitation in the winter period may increase, but warming causes a greater share of rain in the total precipitation amounts, much shorter duration of snow cover and a disappearance of spring thaws, which are an important source of water at the beginning of the vegetation of plants. In Poland two types of low flows of different origin were observed. The summer low flows, preceded by atmospheric and soil drought, begin with a depletion of the catchment retention resources. Summer low flows are generally long-lasting, large-scale and dominant in the lowland part of the country. They often extend into the autumn period and are then called summer-autumn low flows. Winter low flows are characteristic mainly of mountain rivers, although they can also occur in lowland rivers. Their occurrence is associated with longer periods of negative air temperature. In those conditions the surface runoff is stopped, and inflows of groundwater to the riverbeds are severely limited. Ice phenomena in rivers - frazil, pans ice cover, frazil hanging dam, shore ice and anchor ice as well as ice cover and ice jam can block the flow. Winter low flows are usually short-lived and end with a thaw. Nowadays winter low flows rarely occur. Due to the changes in winter runoff processes a soil drought is frequently observed at the end of winter and the beginning of summer season which seriously threatens plants and yields. Summer or summer-autumn droughts do not changed their character.

Enhancing drought resilience is a complex multidisciplinary task involving legal, organizational, technical, financial, research and methodological aspects, although the main measure to cope with drought is to increase the basin retention. The use of various forms of retention allows for multifaceted effects, because each method of collecting water allows for a different scope of its use. We focus here on micro- and small, soil and landscape retention which its main role is to retain water in the environment and slowdown its outflow from the catchment area. An equally important role of these forms of retention is to restore small water cycles when water that falls there sticks around and comes back to earth in the form of rain, dew, mist and fog.

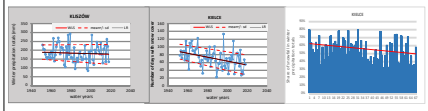
In this study we carry out the assessment and analysis of amount of water that should be stored in vernal ponds to imitate to some extend the former winter runoff regime. Changes in runoff and precipitation characteristics are presented for selected hydrological stations in the Vistula basin.

The River Vistula basin and stations used in the research

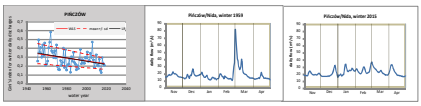


Changes in winter precipitation, surface and groundwater runoff

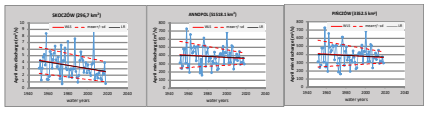
•Winter precipitation totals, number of days with snow cover, .



•Concentration of winter runoff (Gini index and hydrographs).

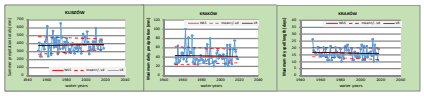


•Groundwater runoff represented by minimum monthly flow.

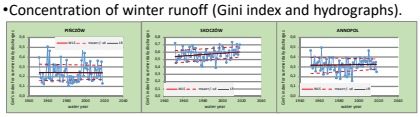


Changes in summer precipitation, surface and groundwater runoff

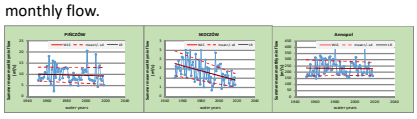
•Summer precipitation totals, maximum precipitation, maximum length of dry spell.



•Concentration of winter runoff (Gini index and hydrographs).



•Groundwater runoff represented by mean minimum monthly flow.



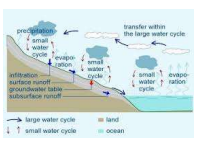
Significant observed changes and their consequences

- The most important changes were detected in winter season. Winters become warmer and almost snowless what makes the soil dry already in early spring what is critical for crop and vegetation in general. River runoff is more uniform without important thaw flood in the end of the season. The decrease in the size and frequency of such floods is beneficial for reduce risk and losses of inundation. However, intensive melting of snow is also a chance for considerable contribution to groundwater and supplementing these resources to the state, which may alleviate shortages of rainfall in the coming months.
- No significant trends in seasonal and annual precipitation totals, maximum daily precipitation and runoff volumes were found. This means that the water cycle is currently governed mostly by the processes of evapotranspiration and groundwater level changes.

Water management measures for enhancing drought resilience (small water retention)

- The main measure to deal with droughts is to keep excess of rainfall or thaw waters in the place where they fell or melted and slowdown its runoff to the river network what results in groundwater recharge and flood risk reduction. This can be done by implement the different forms of small water retention in the river basins.
- Among many technical and non-technical methods of small retention, the most effective are the use of drainage network system and small retention reservoirs. Drainage systems with controlled runoff can be built on flat land. When the landscape is more varied, it is more effective to build small retention reservoirs and reservoirs at the outflow from the drainage system. Similar solutions can be used for outflows from drainage ditch systems.
- Appropriate management of the level of the groundwater table by means of valves in drainage system optimizes the soil moisture to the requirements of crop plants, and increases the amount of fertilizing ingredients available in it (which increases plant yields) and reduces their dispersion in the environment.

Restoration of small water cycles

- Keeping rainfall in the place where they fell can help in restoration of small water cycles. During droughts when there is insufficient water in the land, great flows of solar energy cannot be transformed into the latent heat of evaporation but are changed into sensible heat which additionally warms the air. To activate the small water cycle, it is necessary to increase the roughness of the land so that the water vapor in the air can stick around and comes back to earth in the form of rain, dew, mist and fog.
- 

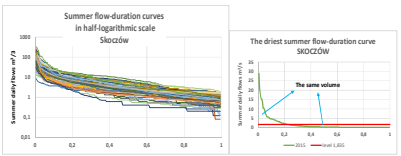
It can be by introduce mid-field plantings and other and other landscape engineering measures.

Small retention program – centralized or decentralized action?

- The central plans of basins choice and methodology of elaborated on the base of hydro-meteorological data and include field reconnaissance (decentralized local activities, i.e. the need for the exact location of retention activities. In addition, a number of restrictions in the implementation of investments, which result from threats to the state of the environment or local legal regulations, should be taken into account. Limitations in the implementation of some small retention tasks may result from:
  - the need to ensure the continuity of the river (effects downstream);
  - existence of protected areas;
  - unfavorable environmental conditions, such as water quality;
  - the need to meet the water needs of present and future users.
- Due to unsufficient density of hydro-meterological observation network the implementation of local monitoring is indispensable and satellites measurements can be also useful.
- In Poland the third stage of small retention reservoirs project starts up and farmers can apply for co-financing of their projects (so, decentralized approach is applied).

Hydrological basis of small retention program

- Simple method well embedded in the hydrological practice can be applied to assess maximum potential retention in the basin: the method of flow-duration or precipitation-duration curves.
- The flow-duration curve is a cumulative frequency curve that shows the percent of time specified discharges or precipitation were equalled or exceeded during a given period (season, year or vegetation period etc.).
- The possible capacity of retention, provided it will be supplied, from river can be calculated on the base of the the flow-duration curve for the driest summer.



Conclusions

- In Poland, almost 25% of the country are areas with a high and very high risk of hydrological droughts. These are, for the most part, areas located in the belt of lowlands, with relatively light soils, where a well-developed agriculture plays an important role in the national economy. These areas need a coherent plan of adaptation to the drought risk which should enhancing drought resilience.
- Most of the actions for small retention are beneficial for the natural environment. However, if poorly designed or planned, these activities can also have a detrimental impact on the environment.
- Promising results may be obtained by using satellite techniques (e.g., IRRIGAT service) to identify areas requiring irrigation and determining their doses, which, combined with the IoT, will make it possible to automate the irrigation process.

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