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OCCURRENCE OF DROUGHTS IN POLAND

Discussion paper transmitted by the Government of Poland [1]

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1. Introduction

One of the negative features of Polish climate is periodical appearance of atmospheric droughts. Normal precipitation in Poland - which usually is about 600 mm annually - should be sufficient for agriculture and other needs. Unfortunately, periodically, long-term, sometimes lasting even several weeks, rainless periods occur. Their appearance is connected with persistent maintenance of a stationary East-European high which, via Central Europe, joins with the Azores anticyclone. In such situations, at lack or insufficient sums of atmospheric precipitation, a drought begins to develop gradually including other elements of the geographic environment. A soil drought appears followed by a hydrologic drought. During a hydrologic drought we observe, among other phenomena, a decrease in the ground water flow into surface waters. This has effects on the reduction of the water flow in rivers. During such periods, a significant drop in the level of underground waters as well as drying of some springs and small watercourses are observed. We can see that there is a strong connection between hydrologic drought concerning surface waters and underground waters. In its initial phase of development, a drought exerts negative effects, first of all, on the proper course of crop vegetation. Intensification of this phenomenon also causes disturbances in proper functioning of other sectors of national economy. Droughts and their negative results do not pose the same threat to the entire area of Poland although, generally speaking, the influence of droughts is stronger than in majority of Central European countries. Poland is considered as a country with poor water resources and one of few European countries threatened with water deficit. Factors responsible for this situation can be divided into two groups:

a/ natural factors of which the most important are:

- low mean annual total atmospheric precipitation (with this regard, of 43 European countries, Poland is in the last ten),
- considerable variation of atmospheric precipitation in time,
- low general water resources (calculated *per capita*, water resources in Poland are over two times lower than in Hungary or France),
- evident predominance of light soils characterised by low field water holding capacity;

b/ factors resulting from historical development of Poland:

- excessive de-forestation,
- predominance of land melioration of drainage character,
- considerable drainage of bogs and marshes,
- restriction of free access to some water resources because of their poor sanitary condition,
- small proportion of surface waters stored in artificial reservoirs (6% of the average annual runoff, while the recommended level is 15-20%) etc.

2. Definition and indices of drought

There is no uniform definition of drought. This results from the fact that droughts may be defined differently depending upon the objectives of an investigation. In „The encyclopedia of climatology” printed in 1987 in USA, they wrote, that drought has been defined in many ways, including: 1/a period of rainfall deficiency; 2/a relative state of forest flammability; 3/a period in which a specific agricultural crop or pasture yield are less than expected amounts; 4/a period in which we observe a critical level of soil moisture or ground water depletion. According to Ogallo (Ogallo, 1989) drought can be considered as a particular situation where water requirements by any kind of system (particularly agricultural ones) exceeds the water supply from all possible natural resources for the region.

Atmospheric or meteorological drought can be described by many indices, for example by Palmer's index called DI (Drought Index) or PDSI (Palmer Drought Severity Index). For calculating this index its necessary to have information about evapotranspiration, soil moisture loss and soil moisture recharge, runoff and precipitation. The score which is received in this way shows the moisture status according to the table which you can see. This method is mainly used in USA. It is relatively difficult to apply because it requires a great number of meteorological and hydrological data. Very simple index is GTK (Selyaninov Hydrothermal Coefficient) which used only two parameters: precipitation and temperature. Drought occurs when the coefficient falls below 1.0. This methodology however was criticised, among others because soil moisture was ignored. In 1993 McKee developed the very simple characteristic of drought - Standardised Precipitation Index (SPI) This index indicates advanced condition of drought. The problem of this method is that the precipitation is the only variable used in its calculation.
In the case of characterisation of the hydrological droughts, there is no uniform methods – usually the changes in water levels are the base of the further analysis.

3. Materials and methods

One of the areas of interests of the Institute of Meteorology and Water Management is continuous monitoring and assessment of the course of meteorological and hydrological phenomena occurring in the entire region of Poland. When preparing an analysis of the course of successive periods of drought spells, specialists from the Institute noticed absence, in appropriate Polish literature, of studies, which could be helpful in comparing this phenomenon with similar ones, which occurred in the past. In an attempt to fill this gap, a monograph was elaborated in which all droughts, which occurred in our country in the period 1891-1995, were catalogued. When describing drought phenomena, three inter-related elements of the natural environment were taken under consideration: meteorological conditions, surface waters and underground waters.
In the mentioned above monograph we used our own methodology. In the case of characterisation of atmospheric droughts, the following indices were applied:
a/ ratio of the height of the atmospheric precipitation in a given period to the sum of multi-annual averages assumed as a norm and expressed in percent (Kaczorowska, 1962):

Table 1

Character of the period	Height of atmospheric precipitation (% of norm)	
	for year, season	for month
average	90 - 100%	75 - 125%
dry	89 - 75%	50 - 74%
very dry	74 - 50%	25 - 49%
extremely dry	below 50%	below 25%

b/ index of the climatic dryness (in other words - climatic water balance), calculated from the following formula:

$$K = P - E \qquad [1]$$

where: K - index of the climatic dryness [mm],
P - atmospheric precipitation [mm],
E - potential evaporation [mm].
(potential evaporation is calculated from Ivanov’s formula:

$$E = 0.\ 0018\ (25 + T)^2\ (100 - f) \qquad [2]$$

where:T - mean air temperature [C],
f - mean relative air humidity [%].

The limiting value of the climatic water balance of 200 mm/year was adopted below which the size of the precipitation deficit indicates the occurrence of an intensive drought and the value of 300 mm/year below which the size of the precipitation deficit indicates a very intensive atmospheric drought. The description takes into consideration only these cases of atmospheric droughts, which occurred on at least 50% of the territory of Poland and lasted minimum 1 month.

The occurrence and course of droughts with reference to surface waters was based on analyses of daily water levels (for years 1891-1950) and daily flows (for years 1951-1995). Low-flow periods were determined on the basis of the limiting water level or flow calculated for each station, i.e. mean level/flow from the lowest annual levels/flows from the multi-annual period 1891-1950/1951-1995. Daily level/flow sequences with values lower than the determined and lasting for at least 21 days were treated as low-flow periods. We decided to define a hydrological drought as a period in which a low-flow was recorded in at least 20% of the stations in the country. Periods of low-flows occurring in summer (called summer-autumn low-flows) and those occurring in winter (called winter low-flows) were analysed separately because of their different origin.

The basis for the isolation of drought spell periods comprising the first horizon of underground waters was the assumption that, on at least 20% of the area of Poland, the level of occurrence of the first horizon of underground waters was by about 50 cm deeper than the multi-annual average for a given month of the year.

4. Results

It was confirmed by the performed analyses that the beginning of atmospheric droughts in Poland occurs most often in spring-summer months, and the course of atmospheric conditions in this period has a decisive role with regards to the depth and areal coverage of this phenomenon. The end of drought usually occurred in winter-spring months (November-February).

With regards to hydrological droughts which comprised the sphere of surface waters, we observed that the occurrence of summer-autumn low-flows depended very much on an atmospheric drought (primarily, on the shortage of atmospheric precipitation). In majority of cases, the beginning of a low-flow period occurred after 2-3 months in which this deficit was significant. The response of flows to the occurrence of precipitation was usually quite rapid, i.e. the end of a hydrological drought commonly occurred in the same (or next) month in which the atmospheric precipitation was close to the norm, or higher.

In the case of winter low-flow periods, their occurrence was associated with appearance of ice on rivers or with long periods of low air temperature (below 0 C) during which the surface flow was arrested and the run-off of ground waters to river troughs was severely restricted.

On the other hand, with regards to the onset of drought spell periods comprising the sphere of the first horizon of underground waters, it occurred most frequently in summer and autumn. This was the result of a shorter or longer deficit of atmospheric precipitations which, additionally, coincide with such elements typical for summer as high field evaporation or vegetation requirements of plants. Relatively few droughts which happened to occur at the end of winter and beginning of spring were caused by relative shortage of underground water resources resulting from their insufficient replenishment which should take place right in this season of the year. These types of drought spell periods were characterized by relatively short duration.

Hydrological droughts in the sphere of underground waters reached their maximum areal coverage most frequently in the winter-spring period. So it was not infrequent that the deficit of underground waters which occurred in the summer-autumn period was further worsened by their unsatisfactory supply also in the winter period.

The end of the phenomenon took place most often in spring or summer. This situations indicates that only the replenishment of underground water resources in the winter-spring period can end hydrological drought in this sphere of geographical environment.

When we analyzed the drought phenomenon, we also paid attention to its duration in Polish conditions. In the result of existing natural conditions, the phenomenon is characterized by the highest stability of its course in the sphere of underground waters and exhibits its highest time and space mobility with reference to atmospheric conditions and surface waters.

The time span of the longest atmospheric drought periods ranged from 9 to 11 months. These types of long-term droughts were, usually, also the most extensive ones with regard to their areal coverage. The peak drought area usually covered from 70 to 95% of the area of Poland. We observed similar dependencies in the case of hydrological droughts. The longest lasting droughts coincided most frequently with those, which were most extensive. The longest low-flow periods lasted more than 180 days. In the case of hydrological droughts comprising the first horizon of underground waters, we identified a few cases of droughts lasting more than one year (maximum of 19 months).
The spacial distribution of the occurrence of drought spell periods in Poland is quite unfavourable from the point of view economy, especially agriculture, because a major part of our agricultural potential is concentrated in regions which are most threatened with the possibility of occurrence of this phenomenon.

5. Conclusions

The recognised mechanisms of the drought phenomenon (systems of meteorological factors favouring occurrence of droughts, their frequency and duration) and mutual interrelations of meteorological and hydrological processes will help develop and improve methods of prognostication of drought spell periods. The author believe that continuos scrunity and careful analysis of the meteorological situation and observation of actual states of soil moisture content will clarify whether the initiated period without rain should be treated as the first stadium of dry spell or (because of the season of year, state of soil moisture content and configuration of meteorological factors) there is no threat of droughts. This, in turn, could prevent significant and unexpected economic losses, especially in agriculture, by allowing controlled management of water resources of a given region.

The results of droughts analyses described in the paper can initiate transformation of data from single-purpose network into a multipurpose management tool and, in this way, to support forecasting drought periods and be helpful for decision-makers.

5. References

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