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Droughts in Poland, 1951-90

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Introduction

One of the negative features of Poland's climate is the periodic occurrence of atmospheric droughts. The most frequent source of this phenomenon is the occurrence of long-term (sometimes lasting several weeks) rainless periods. The occurrence of these periods is connected with the persistence of a stationary east European high that joins with the Azores anticyclone via central Europe. In such situations, with the accompanying lack or insufficiency of atmospheric precipitation, a drought begins to develop gradually. First, a soil drought appears, followed by hydrologic drought. During a hydrologic drought, a decrease in the ground water flow into surface waters is observed, among other phenomena. This results in the reduction of 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 water courses, is observed.

In its initial phase of development, a drought exerts its first negative effects on crops. Intensification of this phenomenon also causes disturbances in other sectors of the national economy. Droughts and their negative results do not pose the same threat to all areas of Poland, although in general the influence of droughts is stronger here than in the majority of central European countries. This situation is the result of a combination of natural and historic factors.

One of the areas of interest of the Institute of Meteorology and Water Management (IMGW) is continuous monitoring and assessment of the course of meteorological and hydrological phenomena occurring in all areas of Poland. When preparing an analysis of the course of successive periods of drought spells, specialists from the IMGW branch in Poznan noticed the absence of similar studies of this phenomenon in Polish literature. In an attempt to fill this gap, they catalogued all droughts that occurred in Poland from 1951 to 1990. The research methods adopted in this study, and also the general characteristics of droughts in Poland, are summarized in this article.

Materials and Methods

When describing drought phenomena, three interrelated elements of the natural environment were taken into consideration: meteorological conditions, surface waters, and underground waters. The criteria used to characterize drought in each of these elements are presented below.

In the case of atmospheric droughts, the following indices were applied:

- ratio of the height of the atmospheric precipitation in a given period to the sum of multiannual averages assumed as a norm, expressed as a percentage (according to Z. Kaczorowska) (see Table 1);
- index of climatic dryness (climatic water balance), calculated from the following formula:

$$K = P - E$$

where K = index of the climatic dryness (mm), P = atmospheric precipitation (mm), and E = potential evaporation (mm);

Character of period	Height of Atmospheric Precipitation (% of normal)	
	Year/Season	Month
Average	90–100	75–125
Dry	89–75	50–74
Very Dry	74–50	25–49
Extremely Dry	below 50	below 25

Table 1. Ratio of the height of the atmospheric precipitation in a given period to the sum of multiannual averages assumed as a norm, expressed as a percentage.

- potential evaporation according to N. N. Ivanov:

$$E = 0.0018\,(25 + T)^2\,(100 - f)$$

where T = mean air temperature (°C) and f = mean relative air humidity (%).

The limiting value of the climatic water balance was defined as 200 mm/year; values below this indicate the occurrence of an intense drought. Values below 300 mm/year indicate a very intense atmospheric drought. The above criteria for identifying atmospheric drought were applied to precipitation data from 131 measurement stations and (in the case of data referring to elements used to calculate potential evaporation) 56 meteorological stations. Only those atmospheric droughts that occurred on at least 50% of the entire area of Poland were considered.

The occurrence and course of droughts with reference to surface waters was based on analyses of daily flows from 50 water-gauging stations in Poland. Low-flow periods were determined on the basis of the limiting flow (Q_G—calculated for each station)—i.e., the mean flow from the lowest annual flows from 1951 to 1990. Daily flow sequences with values lower than the determined flow (Q_G) and lasting for at least 20 days were treated as low flow periods. A hydrological drought was defined as a period in which a low flow was recorded in at least 10 stations in the country. Periods of low flows occurring in summer (summer–autumn low flows) and those occurring in winter (winter low flows) were analyzed separately.

The basis for the isolation of drought 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 about 50 cm deeper than the multiannual average for a given month of the year. The above criterion was applied to data from 73 observation stations.

Results

For the period 1951–90, fourteen droughts were isolated and described. Their distribution in the period is shown in Figure 1. In general, the analyzed periods are unequally distributed. The highest frequency of drought occurrence was noted in the decades 1951–60 and 1981–90. Figure 1 also illustrates the sequence of the occurrence of drought symptoms in various elements of the hydrological system. The development of a hydrological drought is preceded

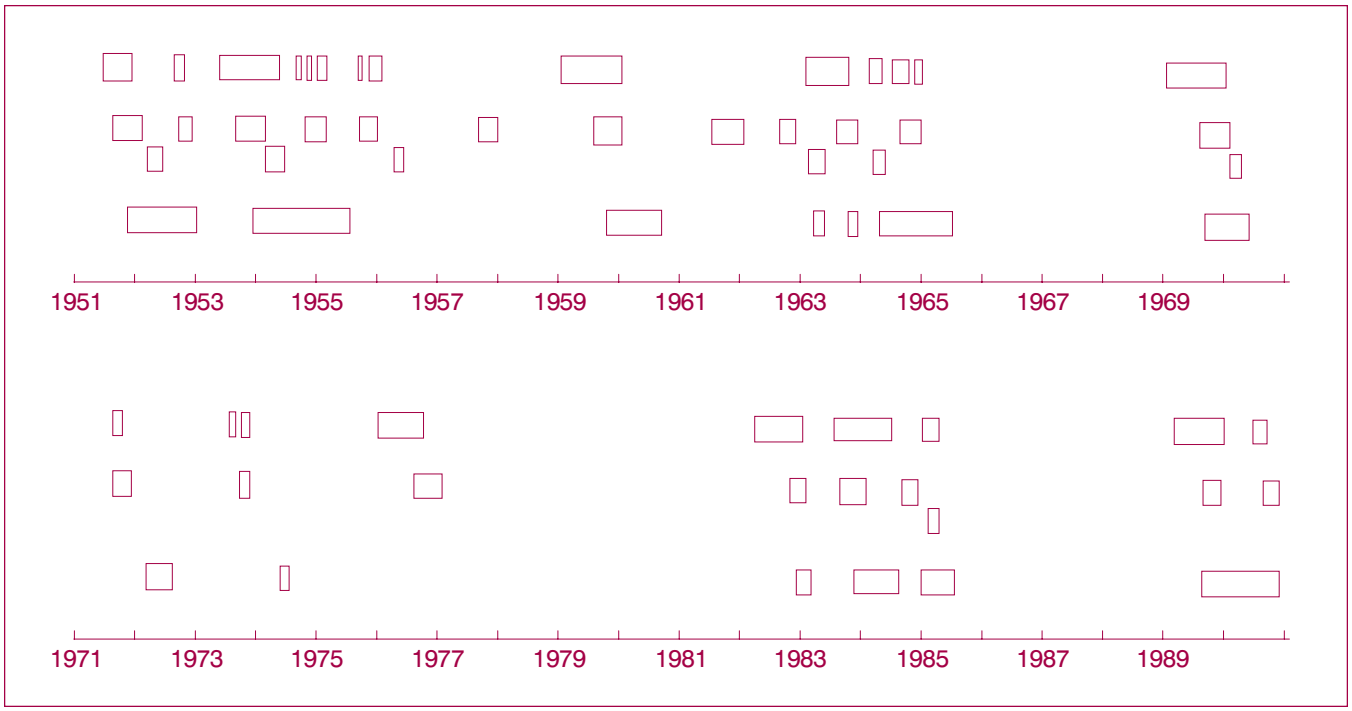

Figure 1. Dry periods in Poland, 1951–90. From top to bottom: first row—atmospheric droughts; second row—hydrological droughts (surface waters), summer–autumn low flows; third row—hydrological droughts (surface waters), winter low flows; fourth row—hydrological droughts (underground waters).

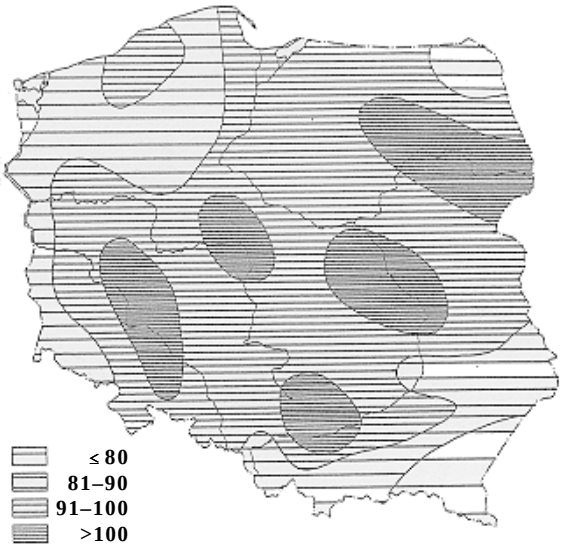

Figure 2. Number of months in atmospheric droughts, 1951–90.

by an atmospheric drought. Analysis confirmed 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 in determining the depth and areal coverage of drought. The end of drought usually occurs in winter–spring months (November–February).

For hydrological droughts affecting surface waters, the occurrence of summer–autumn low flows was observed to have a significant dependence on atmospheric drought (primarily the shortage of precipitation). In most cases, the beginning of a low-flow period occurred 2–3 months after this deficit was significant. The response of flows to the occurrence of precipitation was usually quite rapid—that is, the end of a hydrological drought commonly occurred in the same (or the next) month in which the atmospheric precipitation was close to or greater than normal.

The occurrence of winter low-flow periods was associated with the appearance of ice on rivers or long periods of low air temperatures (below 0°C) during which the surface flow was stopped and ground water runoff to river troughs was severely restricted.

Drought spells comprising the first horizon of underground water occurred most frequently in summer and autumn. These situations typically result in a considerable lowering of the underground water horizon because of a deficit of atmospheric precipitation, which additionally coincides with common summer situations such as high field evaporation. Relatively few droughts occurring at the end of winter or beginning of spring were caused by a relative shortage of underground water resources resulting from insufficient replenishment. These types of drought spells were of relatively short duration.

Hydrological droughts in underground waters reached their maximum areal coverage most frequently in the winter–spring period, so it was not uncommon that the deficit of underground waters that occurred in the summer–autumn period was further exacerbated in winter.

The end of droughts took place most often in spring or summer. This indicates that only the replenishment of underground water resources in the winter–spring period can end hydrological drought.

When analyzing the drought phenomenon, Polish conditions were also considered. As a 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 duration of the longest drought periods ranged from 9 to 11 months, and four such situations were recorded in the 40-year study period. These types of long-term droughts were usually also the most extensive ones in terms of areal coverage. The peak drought area usually covered 70%–95% of Poland. An analysis of all cases of isolated atmospheric droughts showed that the phenomenon occurs most often in the center of the Polish lowland, the central south, and part of northeastern Poland (Figure 2).

Similar dependencies were also observed in the case of hydrological droughts. The longest-lasting droughts coincided most frequently with those that were most extensive, comprising more than 40% of the gauging stations used in the study. The longest low-flow periods lasted more than 180 days. The number of low flows analyzed in the 40-year period varied with each station and ranged from less than 4 to more than 20. Analysis of all the collected data revealed that surface water droughts occurred most frequently in the northern belt of the Great Plains of Poland (Figure 3).

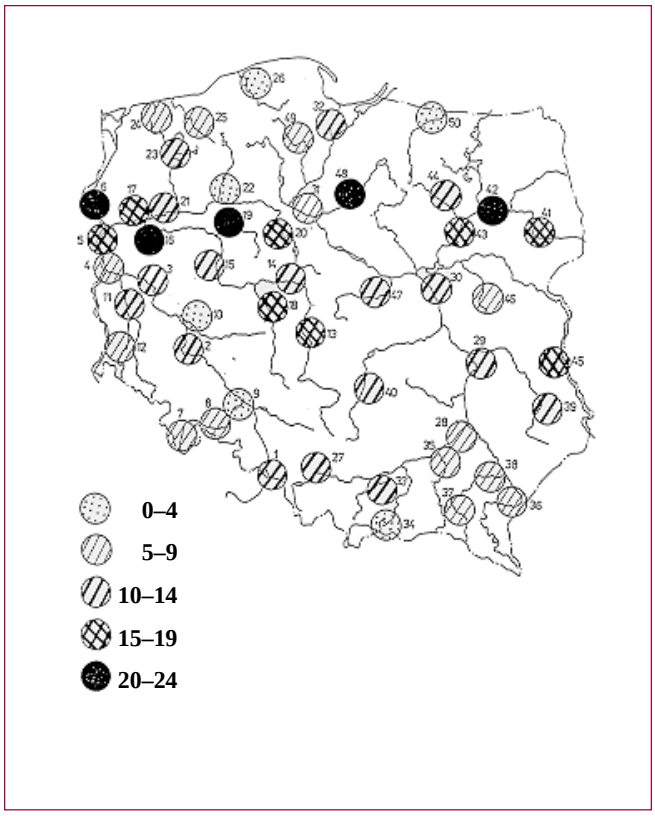

Figure 3. Number of dry periods, 1951–90 (surface waters, low flows).

Figure 4. Number of dry periods, 1951–90 (underground water).

Of the hydrological droughts comprising the first horizon of underground waters, 4 droughts lasting more than a year (maximum of 19 months) were isolated. Analysis of their maximum coverage during consecutive periods of occurrence showed that the phenomenon occurred most often in the central and eastern parts of the belt of the Great Plains (Figure 4).

The spatial distribution of the occurrence of drought spells in Poland outlined above is quite unfavorable for the country's economy, especially for agriculture, because a major part of Poland's agricultural potential is concentrated in regions that are most threatened with the possibility of drought.

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