Drought Mapping in Poland Using *SPI*

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Condensed abstract: The papers gives a brief review on droughts in Poland classified by using the standardized precipitation index *SPI*. Frequency of drought occurrence was calculated using monthly precipitation records in the vegetation periods of 1954–1998 from 31 meteorological stations. According to the Polish meteorological conditions the threshold value of the first class of drought is changed to *SPI* = -0.5. The smaller values of *SPI* indicate the different intensity of drought. The poster contains the maps showing the frequency isolines of moderate, severe and extreme droughts as well as of droughts in all classes.
Key words: atmospheric drought, precipitation deficit, vegetation period, standardized precipitation index *SPI*

1 INTRODUCTION

Poland is situated in a transitory temperate climate zone, influenced by a mild oceanic climate from the west and a dry continental climate from the east. Nonetheless droughts occur posing a serious economic, social and environmental problem. Droughts in Poland are hardly predictable. It is difficult to forecast the term of their occurrence, duration, territorial range and intensity. In spite of this unpredictability and irregularity of drought occurrence in Poland, one may observe some statistical properties of their frequency, duration and the regions affected.

Long term precipitation deficit is a consequence of the anticyclone (high pressure) circulation over the area. In Poland droughts are produced by the Azores and East European anticyclones. Series of such circulations may last for several months – e. g. in 1992 high pressure dominated over Poland from May till the end of August. East European anticyclone, which brings over Poland dry and hot air masses from Balkans and Asia Minor or persistent anticyclone from Azores mostly favour the appearance and development of droughts. The phenomenon is intensified by high temperatures often exceeding 30-33 ºC in the day and 20-18 ºC in the night. Subsiding movements dominate during high pressure circulation, which makes air saturation with water practically impossible.

Climatic conditions in Poland are characterized by a considerable variability in weather during long periods of time (years) as well as short periods (days, weeks). The annual precipitation amounts to 600 mm and during the vegetation period (April-September) reaches on the average 350 mm. The driest regions of Poland are: almost the entire central region, as well as northwestern and mid-eastern parts (Figure 1). These are the regions most threatened by frequent and most severe droughts with the annual rainfall amount often less than 300 mm.

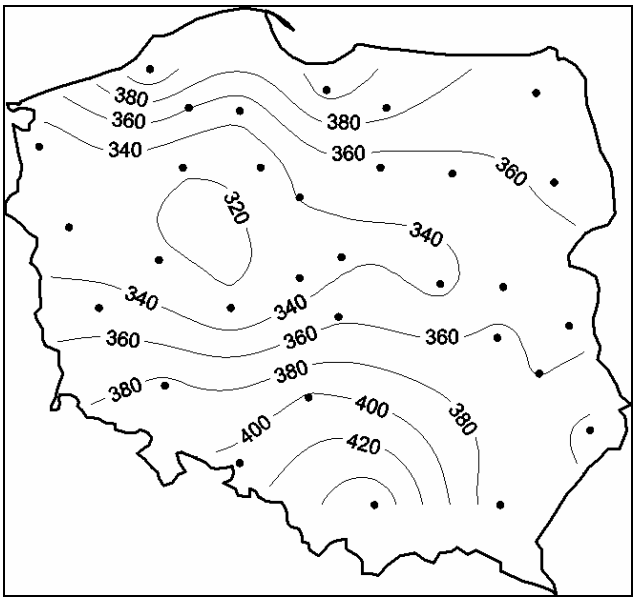

Figure 1. Mean sums of precipitation in the vegetation period (IV-IX) in the years 1954-1998

The paper gives a brief review of spatial distribution of droughts in Poland classified by using the standardized precipitation index *SPI*.

2 MATERIAL AND METHOD

The assessment of severity and frequency of dry periods in a given severity class were made using the standardized precipitation index *SPI* (How to work … 1998, MCKEE et al. 1993, 1995). Long term records of monthly precipitation records in the vegetation periods (April-September) of 1954–1998 from 31 meteorological stations were used for analyses. Appropriate probability distribution is fitted to obtained random sample checking its fitness with statistical tests (χ^2). Atmospheric precipitation is a random variable with the lower limit and often positive asymmetry and does not conform to the normal distribution. Most often periodical (10-days, monthly or annual) sums of precipitation conform to the gamma distribution and therefore precipitation sequence is normalised with the transformation function $f(P)$ (BĄK & ŁABĘDZKI 2002):

$$f(P) = u = \sqrt[3]{x}$$

where: x – the element of precipitation sequence.

Fitness of the distribution of transformed variable $f(P)$ to the normal distribution was tested with the χ^2-Pearson's test and visually by checking whether the values of transformed variable plotted on the normal distribution scale form a straight line.

Values of the *SPI* for a given *P* were calculated from equation:

$$SPI = \frac{f(P) - \mu}{\delta}$$

where: *SPI* – standardised precipitation index, $f(P)$ – transformed sum of precipitation, μ – mean value of the normalised precipitation sequence, δ – standard deviation of the normalised precipitation sequence.

Because of great variability of precipitation in Poland, modification of the *SPI* in the scope of the threshold of the moderate drought class is proposed. It is an attempt of applying this index to detect periods of mild drought, especially in shorter periods, e. g. months. According to this the threshold value of the first class of drought is changed to *SPI* = -0.5. The smaller values of *SPI* indicate the different intensity of drought. Frequency of moderate, severe and extreme droughts in a given month from April to September and in the 6-month growing period was calculated according to the classification shown in Table 1.

Table 1. Classes of drought according to *SPI*

Period	*SPI*
Extremely dry	≤ -2.00
Severely dry	-1.99 ÷ -1.50
Moderetaly dry	-1.49 ÷ -0.50

3 RESULTS

SPI was calculated for particular months and for the whole vegetative period. Based on these results the number of drought periods was established at each station according to the assumed classification (Table 1).

Between 1954 and 1998 totally at all stations there were 2,629 months drier than normal (85 on average), which made up about 30 % of the whole summer season (Table 2). The least contribution was found of extremely dry months – only 8 were noted at each station on average. There were 11 severely dry months at each station on average. Most numerous were moderately dry months – 66 months at each station on average.

At all stations total number of months classified to any drought class achieved the highest values in May (452) and in July (456), whereas the lowest in August (408). The lowest monthly *SPI* in the whole analysed period was noted in September 1970 in Central Poland at the station Piła. Monthly sum of precipitation was 0.0 mm, which corresponded to *SPI* = -4.00. At the station Toruń also in Central Poland in August 1984 monthly sum of precipitation was only 2.7 mm, which corresponded to *SPI* = -3.14 (BĄK & ŁABĘDZKI 2002). The driest summer period (April-September) measured with the *SPI* was that in 1989 in Central Poland (station Polanowice in the Kujawy region). *SPI* for the season (April-September) was equal to -3.47. The other driest summer period was noted in the south-east part of the country (station Zamość) in 1982 (*SPI* = -3.3).

Table 2. Total number of drought events at all stations in months and vegetation seasons in 1954-1998

Period	Number of drought events				Frequency, %
	extremely dry	severely dry	moderetaly dry	total	
April	43	58	341	442	31.7
May	27	68	357	452	32.4
June	41	53	345	439	31.5
July	35	64	357	456	32.7
August	53	54	301	408	29.2
September	43	52	337	432	31.0
April-September	45	54	318	417	29.9

Figure 1 contains the maps showing the isolines of number of all months from April to September classified to moderate, severe and extreme drought class. The maps show the regions with high risk of drought appearance.

Most drought periods according to the *SPI* were recorded in Central Poland. Total number of extremely dry months ranged from 4 to 11, of severely dry – 5 to 18, and of moderately dry – 54 to 80. The highest number of extremely dry months was noted in the central-east part (11 months) and the central-west part (10 months) of the country. Extreme droughts most often occurred in the south-west part and moderate droughts in the central and south regions.

4 CONCLUSIONS

SPI is the standardised index i. e. it refers precipitation to a common reference level. Therefore, one can compare precipitation excess or deficit in various regions and seasons differing in precipitation. Other indices referring the precipitation to the mean value should be used in comparing uniform precipitation sequences of similar mean values. *SPI* is also more useful for atmospheric drought monitoring due to its two features: a possibility of changing the temporal scale and unequivocal results of measurements.

Obtained results on the frequency of months and vegetation periods in the definite drought classes and correlations between *RPI*, *SPI* and the frequencies lead to the conclusions:

Full assessment of *SPI* and its usability for drought monitoring can be done in relation to the drought effects when one attempts to answer the question, how it correlates with the soil or hydrological drought. The division of *SPI* among classes should be further evaluated in reference to the aim and user of the information on the drought severity. The usefulness of *SPI* for the operational, current drought evaluation in shorter periods (week, ten-days) should also be estimated.

5 REFERENCES

Bąk, B. & Łabędzki, L. (2002) Assessing drought severity with the relative precipitation index (*RPI*) and the standardised precipitation index (*SPI*). Journal of Water and Land Development. 6, 89-105.

How to work out a drought mitigation strategy. An ICID Guide. 1998. DVWK Guidelines 309: 29.

McKee, T.B. & Doesken, N.J. & Kleist, J. (1993) The relationship of drought frequency and duration to time scales. Proc. 8th Conference of Applied Climatology, 17-22 January 1993, Anaheim, California, 179-184.

McKee, T.B. & Doesken, N.J. & Kleist, J. (1995) Drought monitoring with multiple time scales. Preprints 9th Conference of Applied Climatology, 15-20 January 1995, Dallas, Texas, 233-236.

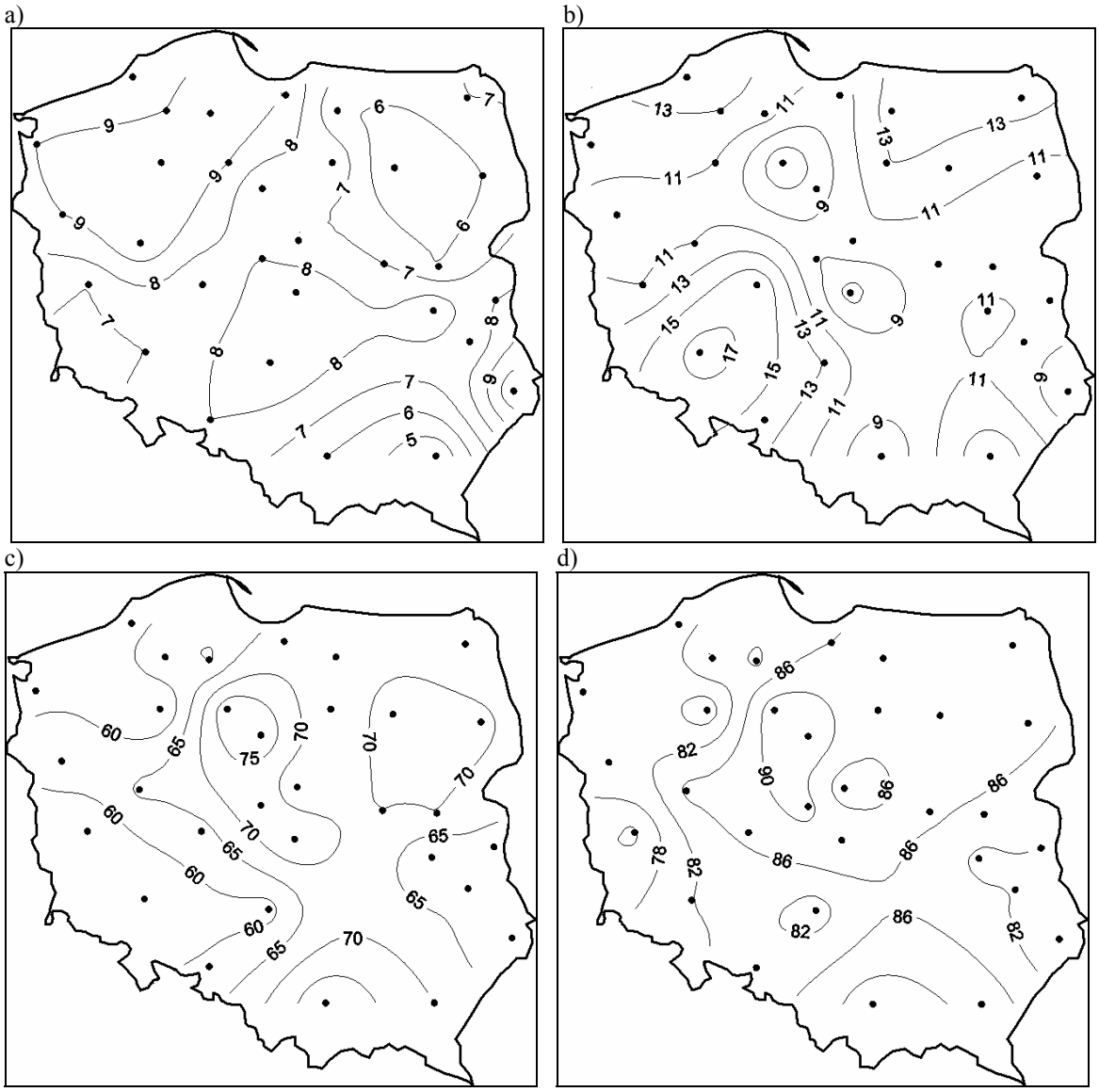

Figure 2. Number of months in the years 1954-1998 in Poland classified to: a – extreme drought, b – severe drought, c – moderate drought, d - total