საქართველოს მეცნიერებათა ეროვნული აკადემიის მოამბე, ტ. 14, №2, 2020
BULLETIN OF THE GEORGIAN NATIONAL ACADEMY OF SCIENCES, vol. 14, no. 2, 2020

Geophysics

Regional Drought Assessment Based on the Meteorological Indices

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The droughts in recent years have become more severe as a result of climate change. The ability to monitor drought conditions and assess its risk is essential to create an effective drought adaptation plan, especially for agricultural ecosystems. Drought indices allow for the characterization of its occurrence and extent. The most widely is used the Standardized Precipitation Index (SPI), which is recommended by the World Meteorological Organization (WMO) as the standard drought index. Although the main cause of drought is lack of rainfall, recent studies have also pointed to the significant role of air temperature and evapotranspiration. The work aimed to determine the monthly values of the meteorological drought indices of the research site Nitra in the period 2014-2018 and to analyze their sensitivity based on the comparison of the determined droughts frequency. We used indexes: SPI (Standardized Precipitation Index), PNI (Percent of Normal Index), DI (Deciles index), MCZI (Modified CZI) and ZSI (Z-score Index), which take into account the values -and distribution of daily precipitation amounts. *© 2020 Bull. Georg. Natl. Acad. Sci.*

Drought, meteorological indices, soil

At the end of 2018, parts of northern and central Europe faced a period of unusually hot weather that led to high temperatures and drought phenomena. These extreme events were linked mainly to increases in temperature and record-breaking heatwaves that have been influencing Europe since 2000, in combination with a lack of precipitation during the summer months. In Slovakia, similar phenomena are observed and a number of works are devoted to the study of these problems [1-5].

Drought monitoring is carried out mainly through drought indices, standardized statistical indicators derived from rainfall-deficit time series [6]. Popular and relatively frequently used drought indices derived from precipitation totals are Standardized Precipitation Index (SPI), Percent of Normal Index (PNI), Deciles Index (DI), MCZI (modified CZI), and ZSI (Z-Score Index). Drought indices are determined by a combination of climatic and meteorological variables, the most important in defining the extent and intensity of drought are daily rainfall totals [7].

The work aimed to determine the monthly values of the meteorological drought indices for the research site Nitra in the period 2014-2018 and to analyze their sensitivity based on the comparison of the determined droughts frequency.

Materials and Methods

The experimental base of the Slovak University of Agriculture in Malanta is situated within the central part of Slovakia. Morphographic typification is mild to moderately rugged hill land. Soil content: Cutani-Haplic Luvisols and Calcic Luvisols, locally eroded and Calcaric Regosols; from loess. Malanta is located in a warm, slightly dry climate with mild winter [8]. The input database consists of daily precipitation totals (*Hz*) for the period 2004-2018.

Meteorological drought indices. *Standardized Precipitation Index.* SPI is a widely used index to characterize meteorological drought on a range of timescales. McKee [9] used the probability of the precipitation occurrence for 3, 6, 12, 24, 48 months, and the output values ranged from -2.0 to 2.0. It was found that the Gamma distribution fits the precipitation time series very well. The Gamma distribution is defined by its frequency or probability density function as:

$$g(x)=\frac{1}{\beta^{\alpha}\Gamma(\alpha)}x^{\alpha-1}e^{\frac{-x}{\beta}}\left(x>0\right),$$

where $\Gamma(\alpha)$ is gamma function; x (mm) is precipitation amount ($x > 0$); α is shape parameter ($\alpha > 0$); and β is scale parameter ($\beta > 0$).

Percent of Normal Index. Index PNI was described by Willeke [10] as a percentage of normal precipitation. It can be calculated for different time scales (monthly, seasonally, and yearly).

PNI is calculated as follows:

$$PNI=\frac{P_i}{P}\times 100,$$

where P_i is the precipitation in time increment (mm); P is the normal precipitation for the study period (mm).

DI (deciles). The DI index was defined as a classification of precipitation totals during a time period over the whole monitoring period [11]. In particular, monthly precipitation totals data are sorted from lowest to highest and are divided into ten equal categories or deciles.

MCZI (modified z-index). The National Climate Center in China developed the CZI in 1995 as an alternative to the SPI index [12]. Assuming that the average precipitation totals have a III. Pearson distribution, CZI is calculated as:

$$CZI_{ij}=\frac{6}{C_{si}}\times\left(\frac{C_{si}}{2}\times\varphi_{tj}+1\right)^{1/3}-\frac{6}{C_{si}}+\frac{C_{si}}{6},$$

where i is the observed time span and j is the current month; CZI_{ij} is the sum of CZI values in the current month (j) during the period i; C_{si} is the skewness coefficient; and φ_{tj} is a standardized variation. The MCZI is calculated using the above formula, and the median precipitation total is replaced by the arithmetic mean value.

ZSI (z-sum). The ZSI index is sometimes confused with the SPI indices. This drought index is an analog to the CZI, but does not work with gamma or Pearson's distribution of precipitation total data. The ZSI can be calculated according to the following formula:

$$ZSI=\frac{P_i-\overline{P}}{SD},$$

where P is the average monthly precipitation total (mm); P_i is the precipitation total in a particular month (mm); and SD is the standard deviation of precipitation totals over the monitoring time interval (mm).

Statistical analysis. Time series of derived drought indices were compared with each other using Pearson correlation coefficient.

Results and Discussion

The course of the calculated SPI values is shown in Fig. 1a. Values oscillating between 0.99 and -0.99 were considered as normal. The severe drought represents values SPI <-1.5 and extreme drought is indicated by values SPI <-2. There were 10 months of severe drought and 4 months of extreme drought based on SPI index during the monitoring period.

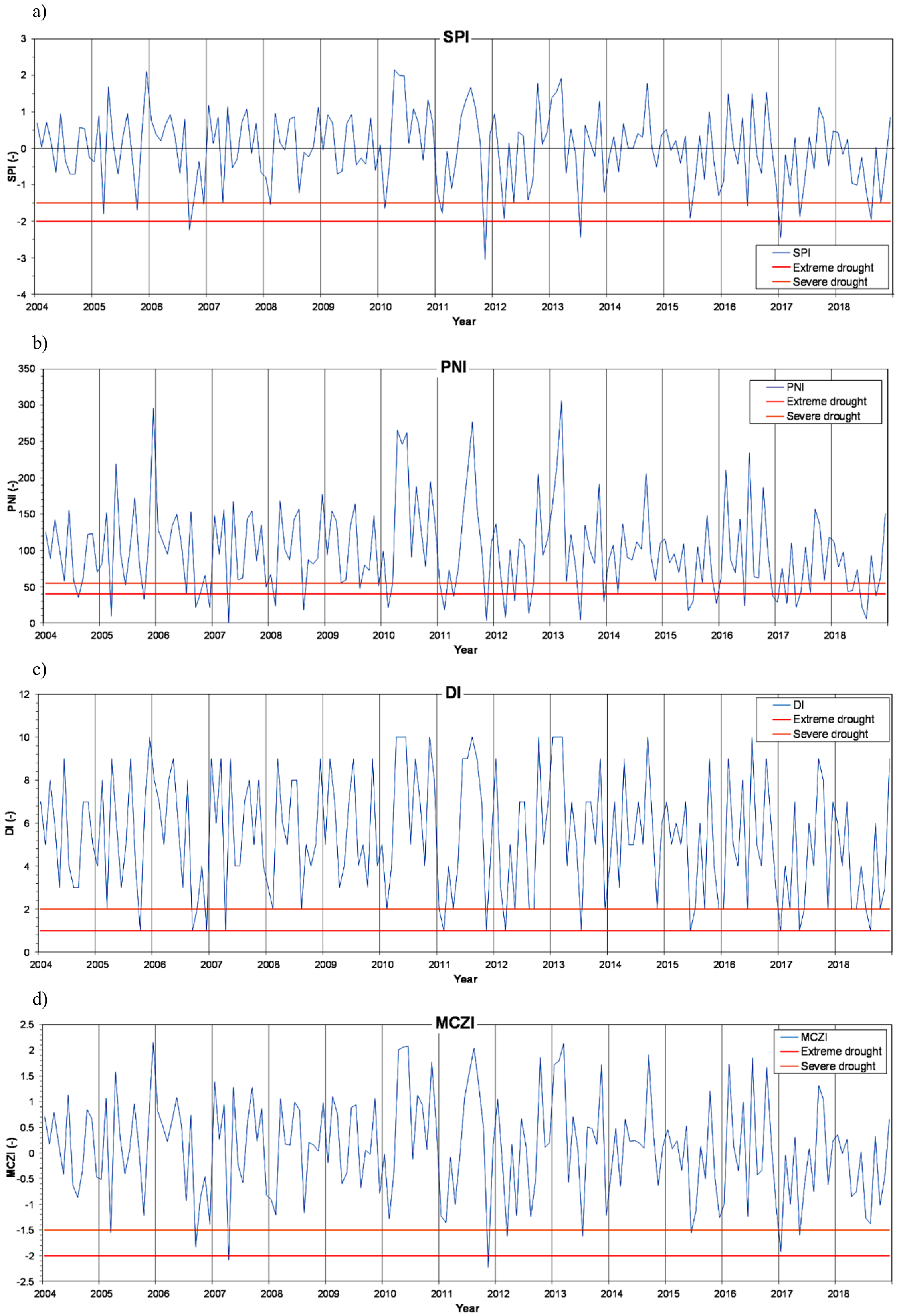

Fig. 1. Values of SPI (a), PNI (b), DI (c), MCZI(d) index for the Malanta site during the period 2004-2018; limit for severe (orange line) and extreme (red line) drought.

e)

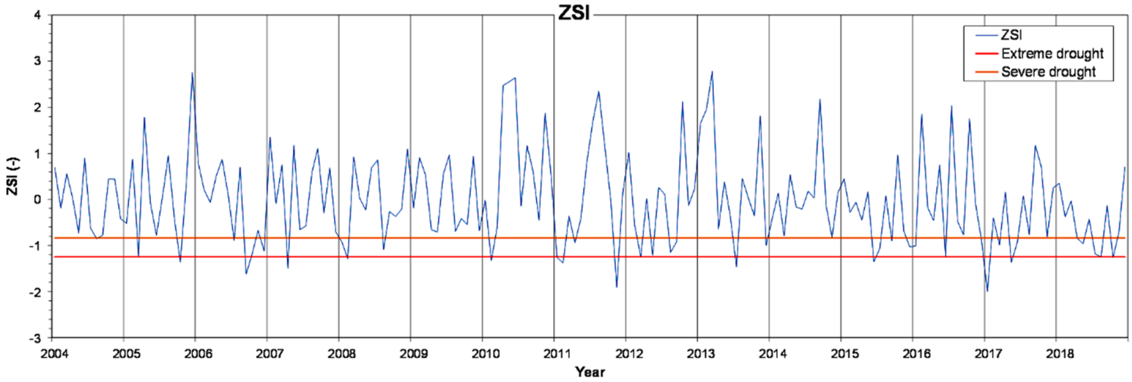

Fig. 1. Values of ZSI(e) index for the Malanta site during the period 2004–2018; limit for severe (orange line) and extreme (red line) drought.

Table 1. Correlation coefficients between assessed meteorological drought indices

PEARSON	SPI	PNI	DI	MCZI	ZSI
SPI	1	0.9419	0.9563	0.9756	0.9606
PNI	0.9898	1	0.9301	0.9752	0.9822
DI	0.9563	0.9301	1	0.9572	0.9497
MCZI	0.9756	0.9528	0.9572	1	0.9693
ZSI	0.9962	0.9822	0.9497	0.9693	1

A graphical presentation of the time series the PNI index is shown in Fig. 1b. The occurrence of severe drought represents a decrease in PNI values below 55, an extreme drought indicates a PNI value below 40. The figure shows that the PNI value falls relatively regularly below the extreme drought level, i.e. the PNI index is more sensitive than SPI. 22 months have been evaluated as extremely dry.

The DI values are shown in Fig. 1c. The severe drought boundary is set at value 2, extreme drought is recorded when DI reaches value 1. 12 months have been evaluated as extremely dry. A comparison of extremely dry months with each other is not possible.

The course of the calculated MCZI index is shown in Fig. 1d. The severe drought boundary represents MCZI <-1.5 and extreme drought is signaled by MCZI <-2. Only 2 months were evaluated as extremely dry according to this index, which is the least of all evaluated indices. MCZI is, therefore, the least sensitive index.

The ZSI index values are shown in Fig. 1e. The occurrence of severe drought represents values below -0.84, extreme drought signals values below -1.25. Based on the results of the evaluation according to this index, there were 13 extremely dry months.

The Pearson coefficients evaluated the correlation between all indices, derived from the set of precipitation totals data are shown in Table 1. The differences were reflected in the sensitivity of the individual indices, i.e. in a different number of months evaluated as severe or extremely dry.

Conclusions

Time series of monthly values of 5 meteorological indices were calculated and the occurrence and extent of drought were evaluated during the monitoring period. The driest years, based on an analysis of the results were the following years: 2018 and 2017, 2015, 2012 and 2006. Based on correlation coefficient values (from 0.9301 to 0.9962), a high correlation rate between all indices was evaluated. The differences were reflected in indices sensitivity, i.e. in a different number of months evaluated as severe or extremely dry. When assessing the weather drought, the authors recommend using the SPI index, because of many existing results, which provide the possibility of comparing individual monitoring sites, and because of the relatively simple calculation method and the appropriate sensitivity of the index.

This work was supported by Scientific Grant Agency No. VEGA 2/0053/18 and is also the result of the project implementation ITMS 26210120009 Infrastructure completion of hydrological research stations, supported by the Research & Development Operational Programme funded by the ERDF

გეოფიზიკა

მეტეოროლოგიური ინდექსების საფუძველზე რეგიონალური გვალვის შეფასება

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ბოლო წლების განმავლობაში, კლიმატის ცვლილების ზემოქმედების შედეგად გვალვები სულ უფრო გამწვავდა. გვალვის ეფექტური საადაპტაციო გეგმის შესაქმნელად, განსაკუთრებით სოფლის მეურნეობის ეკოსისტემებისთვის, აუცილებელია არსებობდეს გვალვის პირობების მონიტორინგის შესაძლებლობები და შეფასდეს შესაბამისი რისკები. გვალვის ინდექსები საშუალებას იძლევა დახასიათდეს ამ მოვლენის არსებობა და მასშტაბი. ნალექების სტანდარტიზებული ინდექსი (SPI) არის გვალვის სტანდარტული ინდექსი, რომელიც რეკომენდებულია მსოფლიო მეტეოროლოგიური ორგანიზაციის (WMO) მიერ და ყველაზე ფართოდ გამოიყენება გვალვის ინდექსებს შორის. მიუხედავად იმისა, რომ გვალვის მთავარი მიზეზი ნალექების ნაკლებობაა, ბოლო დროის კვლევები მიუთითებს, ასევე, ჰაერის ტემპერატურისა და ევატრანსპირაციის მნიშვნელოვან როლზე. ნაშრომის მიზანია 2014-2018 წლებში კვლევის ადგილის – ნიტრას მეტეოროლოგიური გვალვის ინდექსების ყოველთვიური მნიშვნელობების დადგენა და მათი მგრძნობელობის გაანალიზება გვალვების დადგენილი სიხშირის შედარების საფუძველზე. ჩვენ გამოვიყენეთ ინდექსები: SPI (ნალექების სტანდარტიზებული ინდექსი), PNI (ჩვეულებრივი ინდექსის პროცენტი), DI (დეცილეს ინდექსი), MCZI (მოდიფიცირებული CZI) და ZSI (Z – ქულის ინდექსი), რომლებიც ითვალისწინებს ნალექების ყოველდღიური რაოდენობის მნიშვნელობებს და განაწილებას.

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Received March, 2020