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ANALYSIS OF WET PERIODS IN VOJVODINA PROVINCE USING STANDARDIZED PRECIPITATION INDEX

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SUMMARY

In this study, wet periods were analyzed using the Standardized Precipitation Index (SPI) on timescales of 3, 6 and 12 months (SPI3, SPI6 and SPI12) at eight stations in Vojvodina Province during the period 1971-2019. The obtained results show that there were very wet years in the observed period, so that regular maintenance of drainage channels is of great importance. Also, in order to illustrate the wet periods for the area of Vojvodina, maps for a timescale of 6 months (SPI6) were made for the vegetation season (April-September) of 2010. By analyzing the maps, it can be concluded that there were four categories of humidity conditions occurring in the observed period – from normal humidity conditions through moderate to very humid and extremely humid conditions.

Key words: wet periods, Standardized Precipitation Index (SPI), Vojvodina Province

INTRODUCTION

Precipitation is one of the most important factors in the Earth's water cycle (Katsanos et al., 2018). The precipitation regime is affected by climate change (Katsanos et al., 2018), which represents one of the most significant problems facing the whole world (Gulácsi & Kovács, 2015). Climate change is a problem that was noticed not so long ago on the territory of our country and it greatly affects the agricultural activities. In the area of Vojvodina, one of the main tasks of water management is dealing with excess water which occurs as a result of extreme rainfall and removing it from the land and the ground (Bezdan, 2014). The climatic area of Vojvodina is characterized by variability of precipitation, which varies in both distribution and quantity (Pejić et al., 2011). Bošnjak (2001) states that the years with sufficient precipitation and adequate distribution of precipitation are rare. Vojvodina is highly endangered by climate change and climate extremes are expected to become more frequent (Bezdan, 2014). SPI (Standardized Precipitation Index) has become the most commonly used index in the practice of drought monitoring, but it can also be used for the analysis of wet periods, as shown in this paper. Determination of this index requires only precipitation data and it is therefore considered as a very simple and applicable indicator of humidity conditions. SPI is obtained by transforming the probability of occurrence of the observed precipitation into a standardized normal distribution and can be calculated for total precipitation observed for any time interval (Guttman, 1999).

The aim of this paper is to analyze the occurrence of wet periods in the area of Vojvodina. In their research, Seiler et al. (2002) and Guerreiro et al. (2007) state that SPI was developed for the purpose of defining and monitoring droughts, but that it can also be used for the analysis of wet periods. It is difficult to predict when dry or excessively wet periods will occur, as well as their duration and intensity. Planning investments in irrigation systems, sizing of pumping stations and melioration systems and other activities depend on the accuracy and reliability of the forecast of drought or excess water (Bezdan, 2014).

MATERIAL AND METHODS

Climatic characteristics of Vojvodina were analyzed on the basis of meteorological data from eight meteorological stations of the Republic Hydrometeorological Institute of Serbia. Seven stations are located in the area of Vojvodina (Palić, Sombor, Kikinda, Zrenjanin, Rimski Šančevi, Sremska Mitrovica and Vršac), and the eighth station is the meteorological station Belgrade.

Study area

This paper covers the area of Vojvodina. Vojvodina belongs to the southern parts of the Pannonian Plain and occupies the area between 44°37' and 46°11' north latitude and 18°49' and 21°34' east longitude. Vojvodina covers an area of 21,506 km². According to its geographical position, Vojvodina lies in the area of moderately-continental climate (Katić et al., 1979; Lalić et al., 2011). In terms of climate, Vojvodina belongs to the semiarid areas. Hrnjak et al. (2014) state that Vojvodina is characterized by cold winters, hot and humid summers, large temperature ranges during the year and unequal distribution of precipitation by months. Also, the climate of Vojvodina is characterized by warmer autumn compared to spring and a sharper transition from winter to summer (Bezdan, 2014). Precipitation in the area of Vojvodina is spatially and temporally unevenly distributed (Josimov-Dunderski, 2009). The distribution and amount of precipitation in the area of Vojvodina vary throughout the year and the vegetation period. The average annual precipitation in Vojvodina is 615 mm, the average amount of precipitation in the off-vegetation period is 249 mm, while during the vegetation period it is 366 mm (Bezdan, 2019). Precipitation occurs mostly in June, and least in February. Wet periods of Vojvodina were analyzed on the basis of monthly precipitation amounts from eight meteorological stations of the Republic Hydrometeorological Institute of Serbia (RHMZS, 2021). The following stations were considered: Palić, Sombor, Kikinda, Zrenjanin, Rimski Šančevi, Sremska Mitrovica, Vršac and Belgrade (Fig. 1).



Figure 1. Location of investigated area – Vojvodina Province

Standardized Precipitation Index (SPI)

The standardized precipitation index SPI is a simple and popular indicator of humidity conditions. It is determined using only precipitation data and can be calculated for different time intervals, from one months to more than 48 months (Guttman, 1999). SPI was developed by the authors McKee et al. (1993) in order to improve observation of dry and wet periods in relation to PDSI (Palmer Drought Severity Index) (Guttman, 1999).

SPI values for periods from one to three months can be used to assess the humidity conditions in which the growth and development of agricultural crops take place (Benka et al., 2011), while longer time periods are used for the analysis of extreme precipitation (Stričević et al., 2007). McKee et al. (1993) state that the proposed classification was originally limited to drought periods only, but that now the index is commonly used to classify wet periods as

well. Table 1. shows the classification of humidity conditions based on SPI. SPI is based on the probability of precipitation.

Thom (1958) found the gamma distribution to fit well to the climatological precipitation time series. The gamma distribution is defined by its frequency or probability density function:

$$g(x) = \frac{1}{\beta^\alpha \Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta} \quad \text{for } x > 0 \quad (1)$$

in which α and β are the shape and scale parameters respectively, x is the precipitation amount and $\Gamma(\alpha)$ is the gamma function. Maximum likelihood estimations of α and β (Thom, 1958) are:

$$\alpha = \frac{1}{4A} \left(1 + \sqrt{1 + \frac{4A}{3}} \right), \quad \beta = \frac{\bar{x}}{\alpha} \quad \text{where} \quad A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n} \quad (2)$$

and n is the number of observations.

Since precipitation can be 0, the cumulative probability is defined as:

$$H(x) = q + (1 - q)G(x) \quad (3)$$

in which $G(x)$ is the cumulative probability of the incomplete gamma function and q is the probability of zero precipitation defined as:

$$q = \frac{m}{n} \quad (4)$$

and m is the number of zeros in a precipitation time series.

The cumulative probability $H(x)$ is then transformed to the standard normal random variable z with mean zero and variance of one (Abramowitz & Stegun, 1965; Stričević et al., 2007; Tigkas et al., 2013; Tigkas et al., 2015), which is the value of SPI.

Table 1. Classification of humidity conditions according to SPI (McKee et al., 1993)

SPI Values	Classification
2.0 or more	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 or less	Extremely dry

RESULTS AND DISCUSSION

The aim of previous research was to analyze the drought occurrence by using different drought indices. Many scientists and researchers have analyzed the drought occurrence in Vojvodina in this way. This paper shows the possibility of using SPI in order to analyze wet periods in Vojvodina. Based on SPI12 values, several wet periods were recorded in Vojvodina. The most severe wetness was determined during the following periods: 1999-2000, 2004-2005, 2010-2011 and 2014-2015. The diagrams present the values of SPI (SPI3, SPI6 and SPI12) for meteorological station Zrenjanin (Fig. 2). SPI values were calculated using DrinC (Drought Indices Calculator) software. The highest values of SPI (> 2) in the analyzed period were recorded: in 2010 (SPI3 and SPI12) and in 2014 (SPI6).

In addition, the spatial analysis which examined the possibility of occurrence of wet periods is shown on maps made in the QGIS (Quantum Geographic Information System) software for 2010, for months from April to September (Fig. 3). The maps were made on the basis of observed precipitation data at eight meteorological stations. The IDW (Inverse Distance Weighted) method, which belongs to the group of geostatistical interpolation methods, was used to interpolate the SPI values. The coordinates of all eight meteorological stations were used in the national Gauss-Krieger 7 zone coordinate system.

On SPI6 map for April 2010, only two categories of humidity conditions are visible: very humid and extremely humid. For the months of May and June 2010, there are three categories of humidity conditions: from moderately humid to very and extremely humid conditions. And finally, on the maps for the months of July, August and September 2010, there are all 4 categories of humidity conditions: normal, moderately humid, very humid and extremely humid conditions.

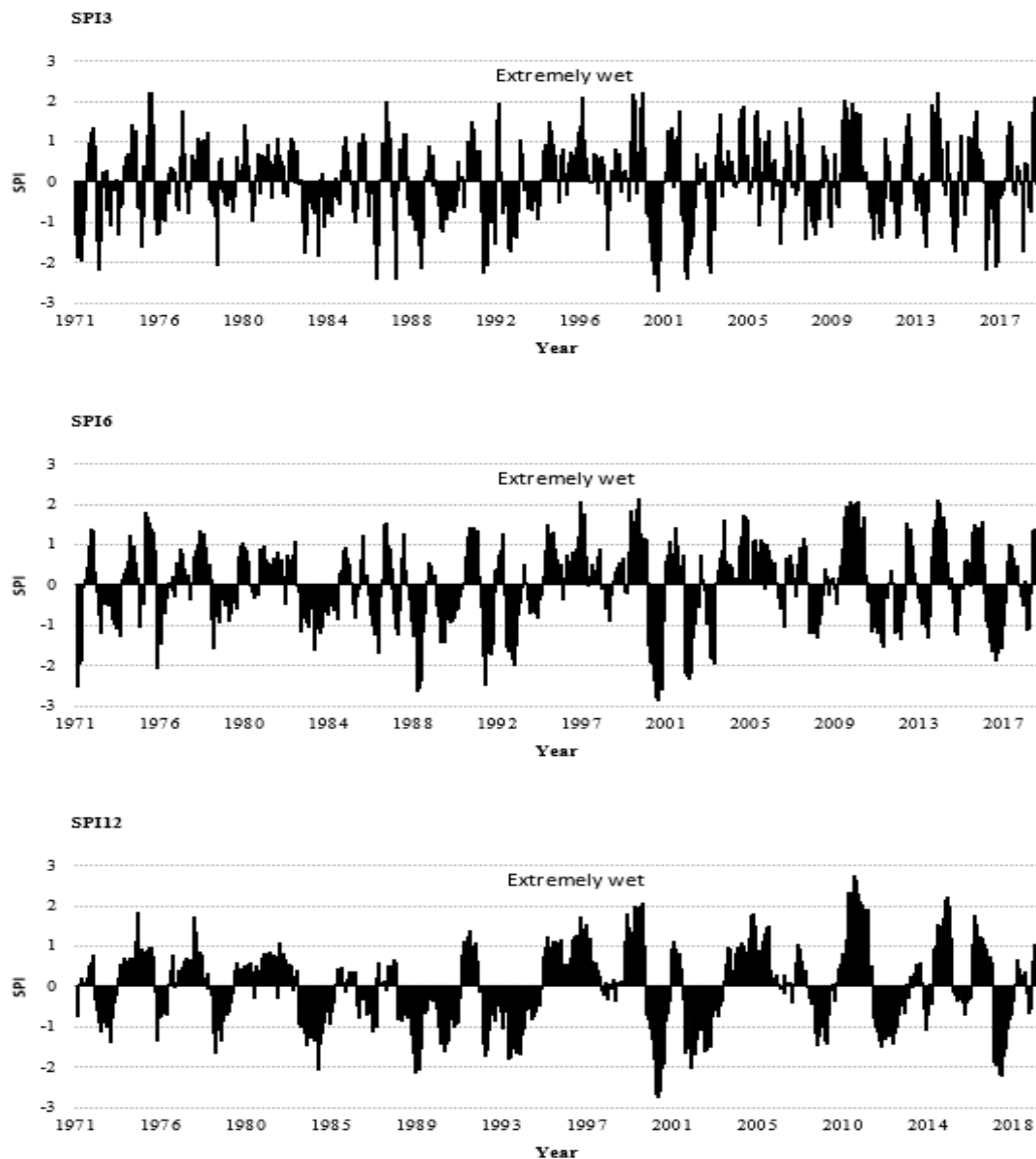


Figure 2. Time series of SPI3, SPI6, SPI12 for meteorological station Zrenjanin (1971-2019)

(a)

(b)

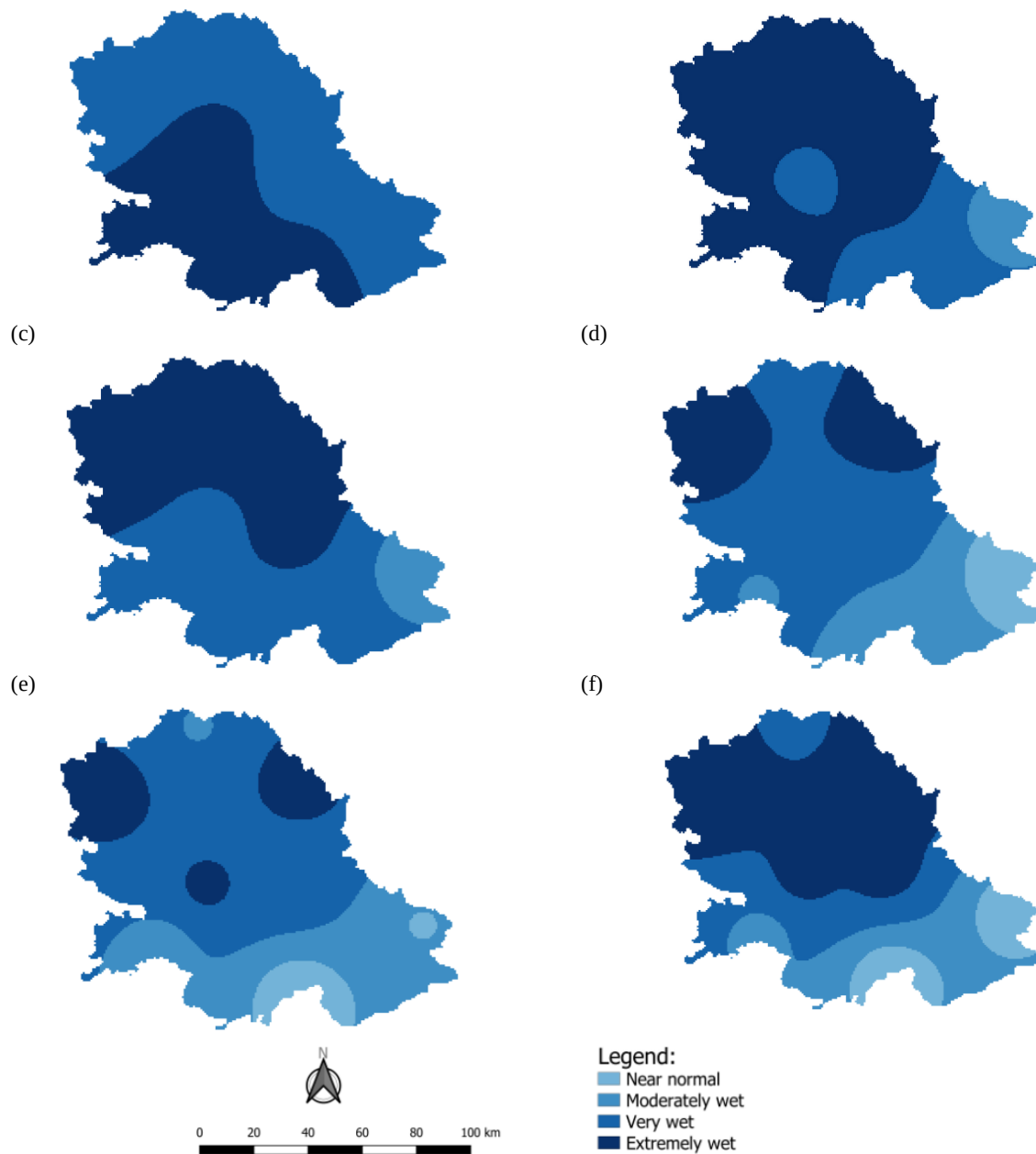


Figure 3. Spatial distribution of SPI6 for (a) April, (b) May, (c) June, (d) July, (e) August and (f) September 2010

CONCLUSION

Climate change is affecting the whole world, and the weather conditions are becoming more and more extreme. At the level of our country, the impact of climate change on agricultural activities is huge. As Vojvodina is lowland, mostly agricultural area, there is an alternating occurrence of problems with excess and lack of water. Heavy rainfall and the existence of groundwater can lead to formation of wetlands, which is often an obstacle to successful agricultural production and timely implementation of agro-technical measures. Wet periods in Vojvodina were analyzed in terms of SPI using monthly precipitation amounts. The meteorological and hydrological conditions were assessed by applying SPI on 3-, 6- and 12-month timescales. SPI12 recorded the following wet periods: 1999-2000, 2004-2005, 2010-2011 and 2014-2015. SPI3 and SPI12 recorded extremely wet conditions in 2010, while SPI6 recorded them in 2014. By comparing the maps for each month, it can be concluded that there were very humid conditions in the observed period (April-September 2010) on the entire territory of Vojvodina. SPI mapping provides

the necessary basis for the analysis and risk assessment of hydrometeorological extremes in order to mitigate the undesirable consequences.

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