ASSESSMENT OF EXTREME LONG-TERM METEOROLOGICAL DROUGHT IN THE NORTHERN PART OF SERBIA

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Abstract

The need to quantify and assess the extreme precipitation deficit is increasing due to climate changing. Long-term precipitation deficits result in the spread of drought to other spheres: hydrosphere and lithosphere, and this leads to negative effects on biodiversity (fauna and flora) as well as human activities such as reduction of electricity production, prevention or elimination of recreational and tourism activities. This paper deals with the assessment of long-term meteorological drought in 5 synoptic stations in the northern part of Serbia. Standardized Precipitation Index was computed in 12-month time scales for identification of extreme meteorological drought for a reference period from 1946 to 2021. The main characteristics of the meteorological drought and relative drought frequency are calculated. The most serious extreme long-term meteorological drought was recorded mainly in 1948 and 2001. The average return period of extreme meteorological drought in the studied area is 11.8 years, but it is specific for each station separately.

Key words: Frequency analysis, Standardized Precipitation Index, extreme episode, meteorological drought, Serbia.

Introduction

Meteorological drought is a recurrent extreme climate event, that begins when deficiency of precipitation occurs over season or over a longer period. The most serious droughts are long-term meteorological drought, which case the occurrence of other types, e.g. agricultural, hydrological or socio-economical drought (Mishra and Singh, 2010). Drought indices are most often used to quantify meteorological drought. Some of mostly used drought indices are: Deciles, Rainfall Anomaly Index, Palmer Z index, Palmer Drought Severity Index, Standardized Precipitation Evapotranspiration Index (WMO and GWP, 2016).

One of the most applied drought indices is Standardized Precipitation Index (SPI). The SPI is a useful index for monitoring dynamics of precipitation and defining the lack of precipitation and its quantitative specification, which is universal for different territories in time and space (McKee et al., 1993; Blain, 2012). The SPI index has attained popularity in the analysis of meteorological drought, despite its weaknesses, which are nicely described by Sienz et al. (2012) and Blain (2012). The SPI is used worldwide to analyze meteorological drought or other physical types of drought.

In this study, the SPI in 12–month time scale is used to identify extreme precipitation deficit, as well as to assess the vulnerability of the northern part of Serbia to this phenomenon. The index is calculated by DrinC software during the years (1946 – 2021) at 5 synoptic stations.

Materials and methods

The case study considers 5 synoptic stations in the northern part of Serbia (Fig. 1), located on the territory of the Balkan Penisula. Values of monthly precipitation are provided by Republic Serbia Hydrometeorological Institute of Serbia for the reference period (1946-2021).

DrinC software (Tigkas et al., 2015) is applied to obtain SPI for 12-month time scale (SPI-12). DrinC software is created with the goal of offering a simple interface for calculating drought indices. The SPI is suitable for diagnosing, defining and monitoring meteorological drought. The risk of meteorological drought can be classified according to the SPI into seven classes. Each of the class has its own probability of occurrence that is shown in Table 1.

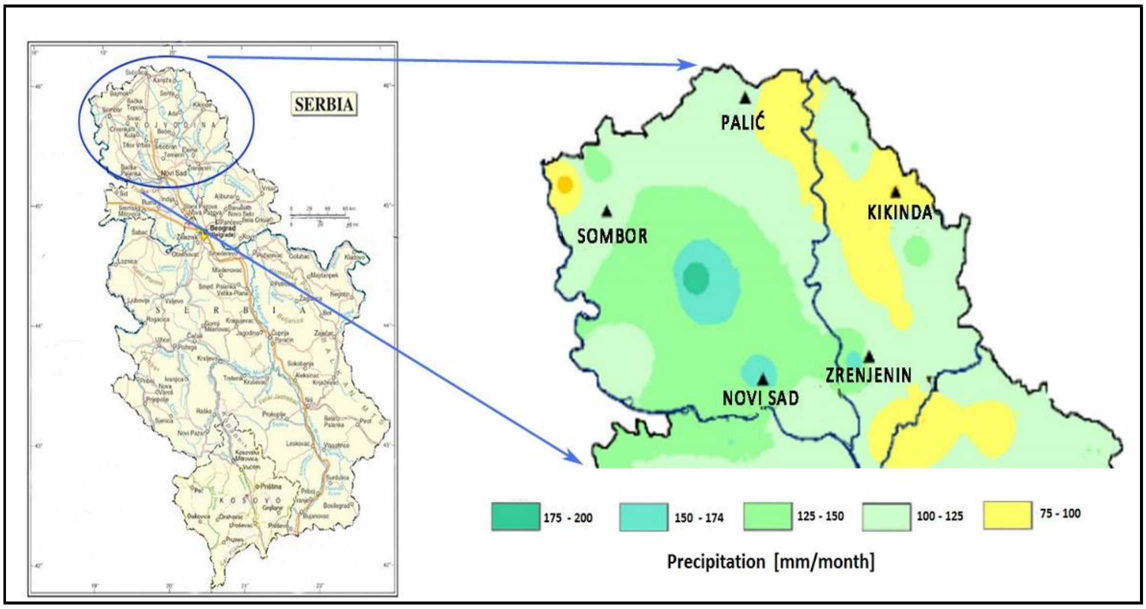


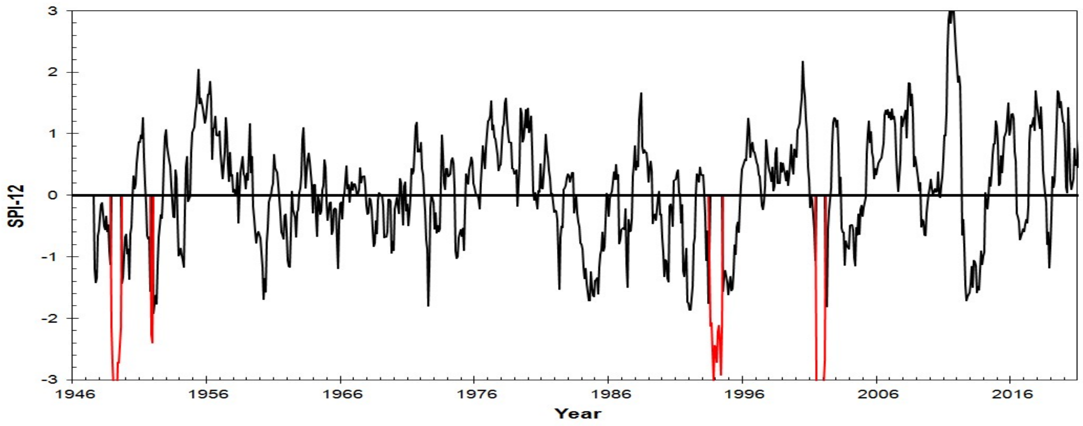
Fig. 1: Location map of the 5 synoptic stations in the northern part of Serbia

Tab. 1: Classes of meteorological drought (Sienz et al., 2012; Blain, 2012).

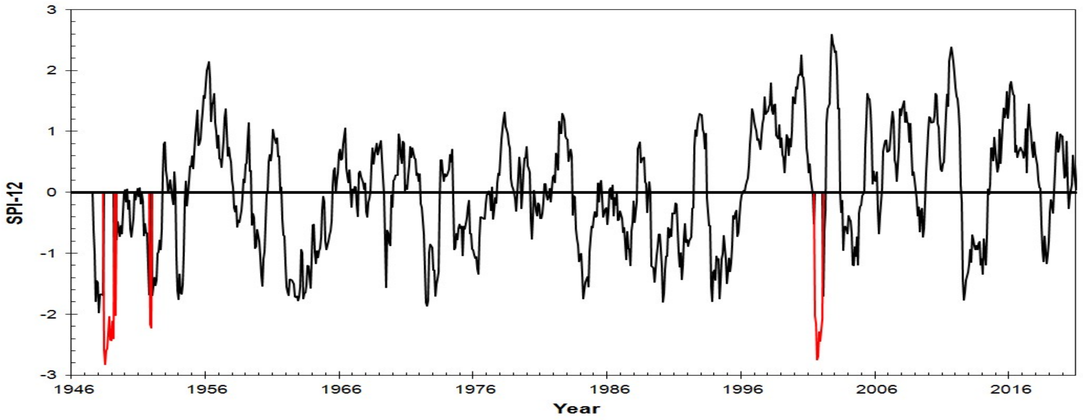
SPI intervals	SPI classes	Probability events
≥ 2	Extreme humidity	2.3%
1.5 to 1.99	High humidity	4.4%
1.0 to 1.49	Mild humidity	9.2%
0.99 to -0.99	Almost normal humidity	68.2%
-1.0 to -1.49	Moderate drought	9.2%
-1.5 to -1.99	Severe drought	4.4%
≤ -2	Extreme drought	2.3%

Results and discussion

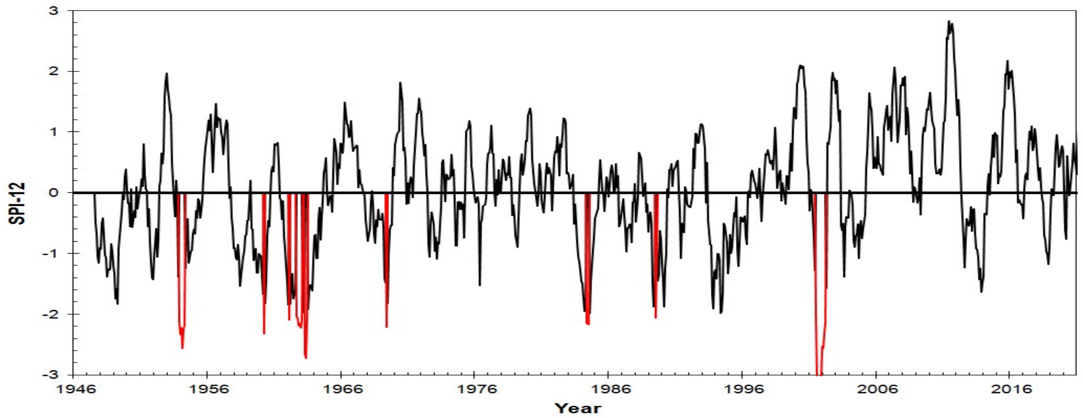
The results of the SPI for drought analysis is presented and evaluated. The results of SPI-12 for five selected stations are shown in Figures 2a to e. The figure presents the results of hydrological year starting from October to September for the period of interest 1946 to 2021. In SPI-12 histograms, extreme meteorological events are identified in red when the SPI value less than (-2). The results of SPI were used to identify duration, severity, intensity and average inter-arrival time for meteorological drought. The results at selected 5 stations are presented in Table 2 for extreme meteorological drought. The total extreme drought events recorded at 5 stations are 34, recorded mainly in 1948 and 2001, with total duration 139 months, cumulative severity of -345.8 and intensity -78.7.



(a) Kikinda



(b) Novi Sad



(c) Palic

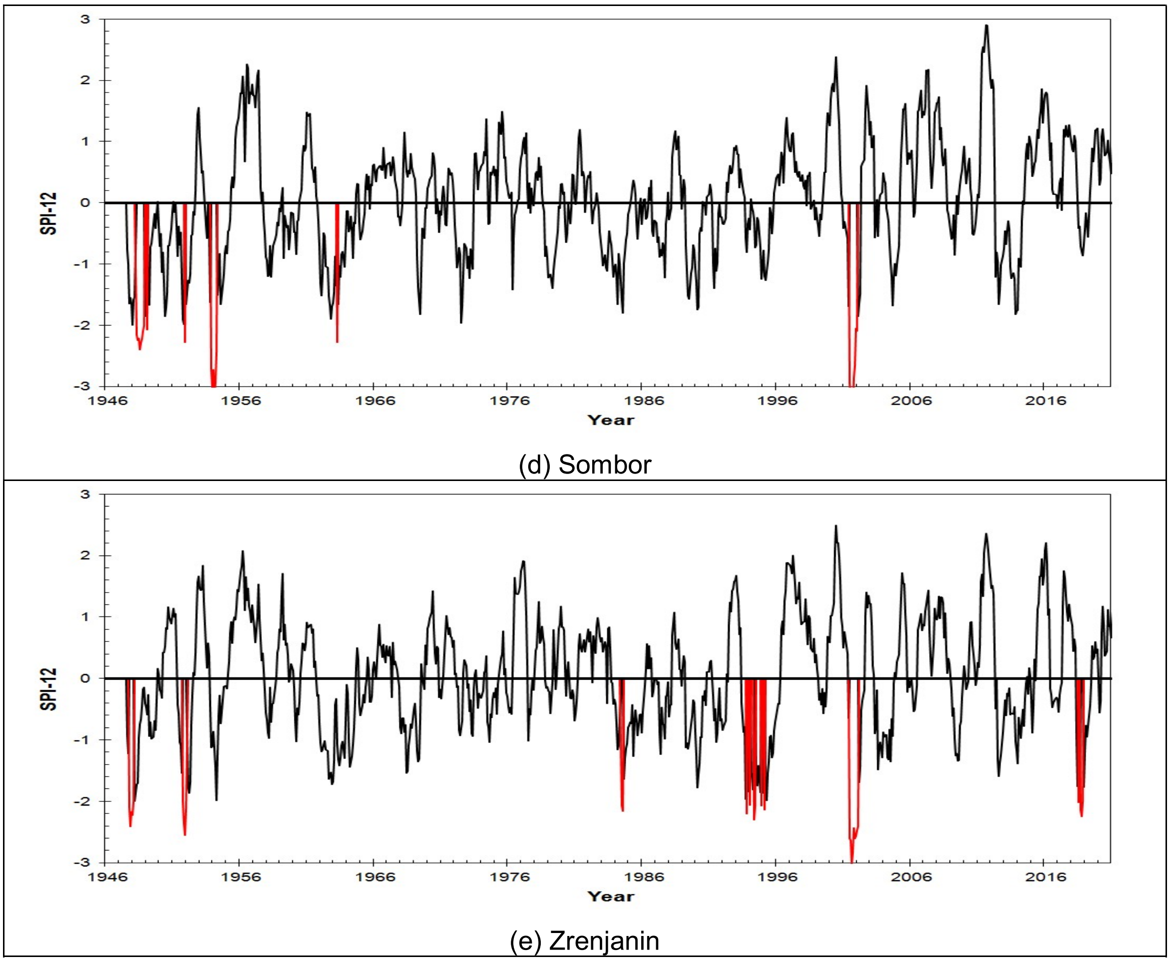


Fig. 2: SPI-12 for the selected 5 stations in the northern part of Serbia for the period 1946-2021

Tab. 2: Extreme episodes of meteorological drought identified by SPI-12 for 5 selected stations

Station	Number of events	Duration	Cumulative severity	Cumulative intensity	Average Inter-arrival time	Years
Sombor	6	25	-63.5	-14.4	10.6	1948,1949 1952,1953 1954,1963 2001,2002
Kikinda	4	32	-89.4	-10.9	17.5	1948,1949 1951,1952 1993,1994 2001,2002
Novi Sad	4	21	-49.4	-8.9	17.7	1948,1949 1951,1952 2001,2002
Palic	9	31	-74.4	-20.5	5.9	1953,1954 1960,1962 1963,1969 1984,1989 2001,2002
Zrenjanin	11	30	-69.1	-24.0	7.1	1947,1948 1951,1952 1984,1993 1994,1995 2001,2002 2018

From Table 2, it is possible to see how the extreme meteorological drought often occurred during the years 1946-2021. An extreme precipitation deficit can be expected on average from 5.9 to 17.7 years. The driest years were mainly in 1948 and 2001.

The most frequent occurrence of extreme meteorological drought was recorded at the Kikinda station, and a slight occurrence of extreme dry episodes was recorded at the station Novi Sad. Table 3 summarizes the relative drought frequency for a 75-year time period and for each observed station.

Tab. 3: Relative drought frequency - RDF

Station	**RDF**
Kikinda	42.7%
Novi Sad	28%
Palic	41%
Sombor	33.3%
Zrenjanin	40%

Conclusion

Extreme meteorological drought is rarely occurring phenomenon whose rarity is changing to regularity as a result of climate changing. Understanding its manifestations in environment leads to proper drought risk management, which ensures mitigate negative impacts on fauna, fluora and human, as well as human activities for this purpose. The SPI-12 was utilized to asses the extreme historical meteorological drought episodes during the years from 1946 to 2021 in the northern part of Serbia. The most sensitive area to extreme meteorological drought is the Kikinda station, where this event is expected to occur more frequently. The two years 1948 and 2001 saw the most extreme long-term meteorological droughts ever documented. In the studied region, the average return period for extreme meteorological drought is 11.8 years, but it varies for each station individually. The results of the SPI analysis can serve as a basis of the proposal of operational measures in the given territory to minimize or eliminating the averse effects of risk of drought.

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Souhrn

Potřeba kvantifikovat a vyhodnocovat extrémní srážkový deficit se v důsledku změny klimatu zvyšuje. Dlouhodobý deficit srážek vede k rozšíření sucha do dalších sfér: hydrosféry a litosféry, a to má negativní dopady na biologickou rozmanitost (faunu a flóru) i lidské aktivity, jako je snížení výroby elektřiny, zamezení nebo vyloučení rekreačních a turistických aktivit. Tento článek se zabývá hodnocením dlouhodobého meteorologického sucha na pěti synoptických stanicích v severní části Srbska. Pro identifikaci extrémního meteorologického sucha za referenční období 1946-2021 byl vypočten standardizovaný srážkový index ve 12měsíčním měřítku. Byly vypočteny hlavní charakteristiky meteorologického sucha a relativní četnost sucha. Nejzávažnější extrémní dlouhodobé meteorologické sucho bylo zaznamenáno především v letech 1948 a 2001. Průměrná doba návratu extrémního meteorologického sucha ve studované oblasti je 11,8 roku, je však specifická pro každou stanici zvlášť.

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