Journal of Hydrology 494 (2013) 32–42

Contents lists available at SciVerse ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Analysis of precipitation and drought data in Serbia over the period 1980–2010

Milan Gocic *, Slavisa Trajkovic

Faculty of Civil Engineering and Architecture, University of Nis, A. Medvedeva 14, 18 000 Nis, Serbia

ARTICLE INFO

Article history:
Received 21 December 2012
Received in revised form 31 March 2013
Accepted 28 April 2013
Available online 6 May 2013
This manuscript was handled by Andras Bardossy, Editor-in-Chief, with the assistance of Purna Chandra Nayak, Associate Editor

Keywords:
Trend analysis
Precipitation
Drought
Statistical tests
Serbia

SUMMARY

Precipitation and Standardised Precipitation Index (SPI) trends were analyzed by using linear regression, Mann–Kendall and Spearman's Rho tests at the 5% significance level. For this purpose, meteorological data from 12 synoptic stations in Serbia over the period 1980–2010 were used. Two main drought periods were detected (1987–1994 and 2000–2003), while the extremely dry year was recorded in 2000 at all stations. The monthly analysis of precipitation series suggests that all stations had a decreasing trend in February and September, while both increasing and decreasing trends were found in other months. On the seasonal scale, there were the increasing trends in autumn and winter precipitation series, while on the annual scale the most of the stations had no significant trends. Besides, the decreasing trend was found at the Belgrade and Kragujevac stations, while the other stations had the increasing trend for the SPI-12 series.

1. Introduction

Drought is a natural phenomena on whose occurrence varies in frequency, severity and duration. Moreover, drought is both a hazard and a disaster (Paulo et al., 2012). It can be classified as meteorological, agricultural, hydrological or socio-economic drought. There were numerous studies on drought (Moreira et al., 2008; Paulo and Pereira, 2008; Shahid, 2008; Khalili et al., 2011; Mishra and Singh, 2010; Tabari et al., 2012) and a variety of indices for describing drought have been developed. Trends in drought occurrence frequency or its duration can be explained through the changes in precipitation (Hisdal et al., 2001).

Precipitation is one of the most important meteorological variables which can impact the occurrence of drought or flood. Analysis of precipitation and drought data yields important information which can be used to improve water management strategies, protect the environment, plan agricultural production or in general, impact economic development of a certain region.

In recent years, a plethora of scientists worldwide have compared and analyzed the precipitation trends (Gemmer et al., 2004; Partal and Kahya, 2006; Liu et al., 2008; Oguntunde et al., 2011; Tabari and Hosseinzadeh Talaee, 2011; Tabari et al., 2012). In Europe, Brunnetti et al. (2001) analyzed trends in daily intensity of precipitation during the period 1951–1996 and detected the significant positive trend in northern Italy. Tolika and Maheras (2005) studied the wet periods for the entire Greek region. They showed that the longest wet periods are observed in Western Greece and in Crete, while stations in the Central and South Aegean area had the shortest wet periods. In Bulgaria, Koleva and Alexandrov (2008) analyzed the long-term variations in precipitation and concluded that the last century can be divided into several wet and dry periods with duration of 10–15 years. Niedźwiedź et al. (2009) discussed the patterns of monthly and annual precipitation variability at seven weather stations in east central Europe during the period 1851–2007. They also identified the dry period in the 1980s and the first half of the 1990s. Ruiz Sinoga et al. (2011) observed the temporal variability of precipitation in southern Spain to detect trends and cycles and noted the general decreasing trend in seasonal precipitation.

Furthermore, there have been a number of precipitation studies and reports for different periods and locations in Serbia. For example, Tosic (2004) investigated spatial and temporal variability of winter and summer precipitation at 30 stations for the period 1951–2000, while Unkasevic and Tosic (2011) statistically analyzed the daily precipitation over Serbia during the period 1949–2007. Besides, Tosic and Unkasevic (2005) and Djordjevic (2008) studied precipitation trend in Belgrade to provide informa-

* Corresponding author. Tel.: +381 64 1479423; fax: +381 18 588200.
E-mail address: mgocic@yahoo.com (M. Gocic).

0022-1694/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jhydrol.2013.04.044

tion on climate variability. However, a comprehensive analysis of trends and variability in precipitation series over Serbia as presented here is still lacking.

The objectives of this study are: (1) to research variability in precipitation on monthly, seasonal and annual time series by using the linear regression, Mann–Kendall and Spearman's Rho methods; (2) to consider the impact of serial correlation in detecting trends; and (3) to investigate the drought in Serbia between 1980 and 2010.

2. Materials and methods

2.1. Study area and data collection

The study area was Serbia which is located in the central part of the Balkan Peninsula with an area of 88.407 km^2. Its central and southern areas consist of highlands and mountains, while the northern part is mainly flat. The climate of the country is temperate continental, with a gradual transition between the four seasons of the year.

Series of monthly precipitation data were collected from 12 synoptic stations from Serbia (Fig. 1) for the period 1980–2010 and were obtained from Republic Hydrometeorological Service of Serbia (http://www.hidmet.gov.rs/). The geographical description of the selected synoptic stations is given in Table 1.

The precipitation datasets were investigated for randomness, homogeneity and absence of trends. The autocorrelation analysis was applied to the precipitation monthly time series of each station. The quality of precipitation data were controlled with double-mass curve analysis (Kohler, 1949).

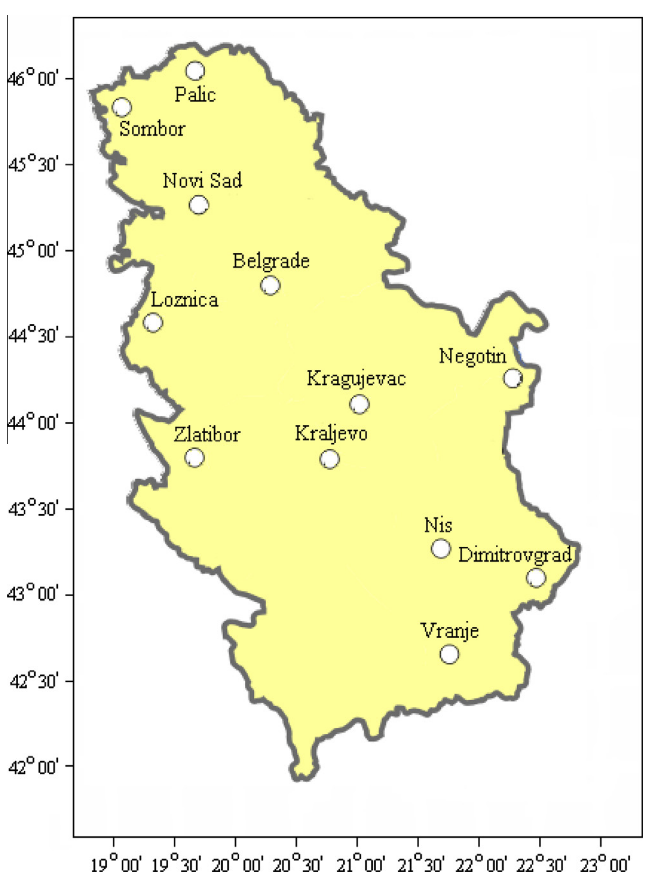

Fig. 1. Spatial distribution of the 12 synoptic stations in Serbia map.

Table 1
Geographical descriptions of the synoptic stations used in the study.

Station name	Longitude (E)	Latitude (N)	Elevation (m a.s.l.)
1. Belgrade	20°28′	44°48′	132
2. Dimitrovgrad	22°45′	43°01′	450
3. Kragujevac	20°56′	44°02′	185
4. Kraljevo	20°42′	43°43′	215
5. Loznica	19°14′	44°33′	121
6. Negotin	22°33′	44°14′	42
7. Nis	21°54′	43°20′	204
8. Novi Sad	19°51′	45°20′	86
9. Palic	19°46′	46°06′	102
10. Sombor	19°05′	45°47′	87
11. Vranje	21°55′	42°33′	432
12. Zlatibor	19°43′	43°44′	1028

Table 2
Drought classification of SPI.

Drought class	SPI value
Non-drought	SPI $\geqslant 0$
Near normal	$-1 <$ SPI < 0
Moderate	$-1.5 <$ SPI $\leqslant -1$
Severe/extreme	SPI $\leqslant -1.5$

2.2. Aridity index

An aridity index is a numerical indicator of the degree of dryness of the climate at a given location. A number of aridity indices have been proposed. In this study, the UNEP index (UNEP, 1992) was used. According to the ratio of precipitation (P) and potential evapotranspiration (PET), regions were classified from hyper-arid to humid. PET was estimated from the FAO-56 Penman–Monteith (FAO-56 PM) equation, which is the standard equation for estimating reference evapotranspiration (ET$_0$). It calculates ET$_0$ as (Allen et al., 1998):

$$ET_0 = \frac{0.408 \cdot \Delta \cdot (R_n - G) + \gamma \cdot \frac{900}{T+273} \cdot U_2 \cdot VPD}{\Delta + \gamma \cdot (1 + 0.34 \cdot U_2)} \quad (1)$$

where ET$_0$ = reference evapotranspiration (mm day^{-1}); Δ = slope of the saturation vapor pressure function (kPa °C^{-1}); R_n = net radiation (MJ m^{-2} day^{-1}); G = soil heat flux density (MJ m^{-2} day^{-1}); γ = psychometric constant (kPa °C^{-1}); T = mean air temperature (°C); U_2 = average 24-h wind speed at 2 m height (m s^{-1}); and VPD = vapor pressure deficit (kPa).

The locations were then classified as hyper-arid (P/PET $\leqslant 0.05$), arid ($0.05 < P$/PET $\leqslant 0.2$), semi-arid ($0.2 < P$/PET $\leqslant 0.5$), sub-humid ($0.5 < P$/PET $\leqslant 0.65$) or humid (P/PET > 0.65).

2.3. Rainfall variability index

Rainfall variability index (δ) is calculated as:

$$\delta_i = (P_i - \mu)/\sigma \quad (2)$$

where δ_i = rainfall variability index for year i, P_i = annual rainfall for year i, μ and σ are the mean annual rainfall and standard deviation for the period between 1980 and 2010. A drought year occurs if the δ is negative.

According to WMO (1975), rainfall time series can be classified into different climatic regimes:

$$\begin{aligned} &P < \mu - 2 \cdot \sigma \quad \text{—extreme dry} \\ &\mu - 2 \cdot \sigma < P < \mu - \sigma \quad \text{—dry} \\ &\mu - \sigma < P < \mu + \sigma \quad \text{—normal} \\ &P > \mu + \sigma \quad \text{—wet} \end{aligned} \quad (3)$$