Comparison and analysis of drought indices SPI & SPEI for Belgrade (Serbia) for the period of 1961-2020

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1. Introduction

We rely on different indices to quantify on water availability and drought status in a region, and in everyday use, we face the dilemma of using more simple or complex indices, depending on our intentions. Out of these indices, the *standardized precipitation index* (**SPI**) & *the standardized precipitation evapotranspiration index* (**SPEI**), are some of the most widely used. As their name implies, these indices standardize precipitation (both) and evapotranspiration (SPEI only) over a single point for a certain time period and use that as a reference for an estimate of available water. Analysis was performed for ***Belgrade, Republic of Serbia***, for the time period of 1961-2020 using measured data.

2. Data and method

SPI and SPEI are calculated using monthly rainfall sums. They quantify observed precipitation as a standardized departure from a selected probability distribution function that models the raw precipitation data. Here, it was assumed that rainfall conforms to the Gamma distribution. Different time periods are suitable for characterizing a range of processes, depending on their individual scale. For example, shorter time scales reflect water needs of dry land agriculture, while longer time scales reflect water availability in smaller wells and aquifers.[1] The difference between these two indices lies in the fact that SPEI takes (potential or measured) evapotranspiration into account, while SPI does not.

Evapotranspiration consists of two processes, water evaporation into the atmosphere from the soil, and transpiration - water movement from the soil to the atmosphere via plants.

Precipitation and temperature data were acquired from the station network of the Republic Hydrometeorological Service of Serbia (RHMS). Station coordinates are 44°48'N, 20°28'E; H:132m. As sufficient directly measured evapotranspiration data was not available, potential evapotranspiration was used, calculated by the Thornthwaite method which takes into account temperature and latitude of a certain point.[2] Since SPI & SPEI can be computed using rainfall sums of differing length, in this work indices for the 3, 6 and 12-month sums were calculated and compared. Calculations were performed using the *Climate indices in Python* package written in the Python programming language.[3] The presence of trends was checked using the Mann-Kendall statistical test,[4] using the python module *pymannkendall*.[5] The test was applied on the whole data series and on summer values. In addition to this, station temperature and rainfall measurements were tested. Summer values of each year were depicted as the sum of SPI and SPEI values for the months of June, July and August. Dry and wet periods were classified as described in McKee et al (1993), shown on Table 1.

For the sake of readability, graphs are shown for indices calculated using the 12 month sum (SPI12 and SPEI12).

Table 1

Drought intensity according to McKee et al.(1993)

Category	Index value
Extremely wet	2.00 or more
Severely wet	1.50 to 1.99
Moderately wet	1.00 to 1.49
Near normal	−0.99 to 0.99
Moderately dry	−1.00 to −1.49
Severely dry	−1.50 to −1.99
Extremely dry	−2.00 or less

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3. Results and discussion

Derived index values are depicted on Figs. 1 and 2. Despite high correlation between the two indices, with r > 0.9, as seen on Fig. 3, dry periods are characterized quite differently by the respective indices, for all three calculation periods. Comparatively, SPI shows a drier earlier period, while SPEI tends to display a drier period after the year 2000, which is visible on Fig. 4. Similarly, it can be observed for the duration of dry periods (consecutive months with the respective index lower than -1), illustrated by Fig. 5. Indices calculated using longer monthly sums depict longer continuous dry periods, with SPEI12 for example, having a total of 49 dry months (index value lesser than -1), with the number being only 21 for SPI12 for the second decade of the 21st century. The longest continuous dry period for SPEI12 is 16 months long in the same decade, and only 7 months for SPI12. Meanwhile, for the earlier part of the time period, SPI tends to show more dry periods than SPEI.

During the statistical analysis of the data, the Mann-Kendall test yielded a significant trend only for SPEI, with a decreasing tendency for all three calculation periods, which is depicted for SPEI12 on Fig. 6. This is an important discovery because indices taking sums over longer time scales should have no trend in the data, unless there is a change in rainfall and/or temperature patterns.

A stronger SPEI12 summer trend was detected, with the slope of -0.053. This would be the only significant trend observed in summer values.

Also, a rising trend in measured station monthly average temperature was detected, shown on Fig. 7.

All of the aforementioned trends were found with a significance level of 1%, except the SPEI12 summer tendency, which was found for the significance level of 5%. No significant trends in rainfall data were detected for the duration of the whole time period.

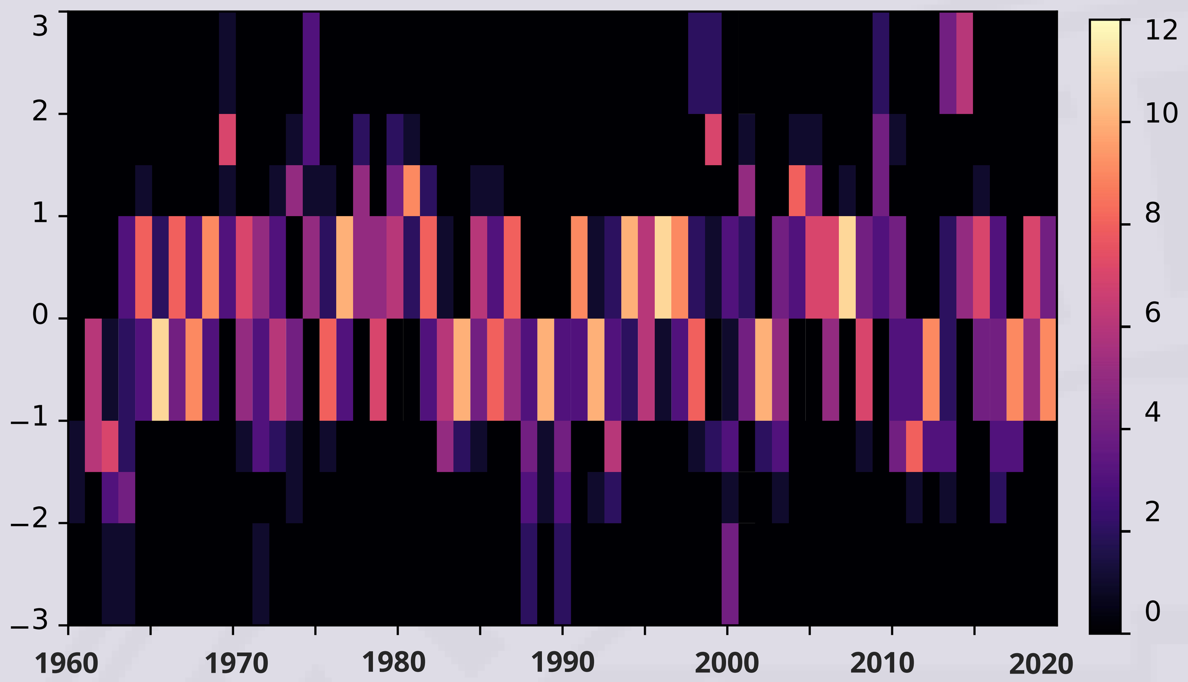

Fig. 1 *Histogram of SPI12 values over time*

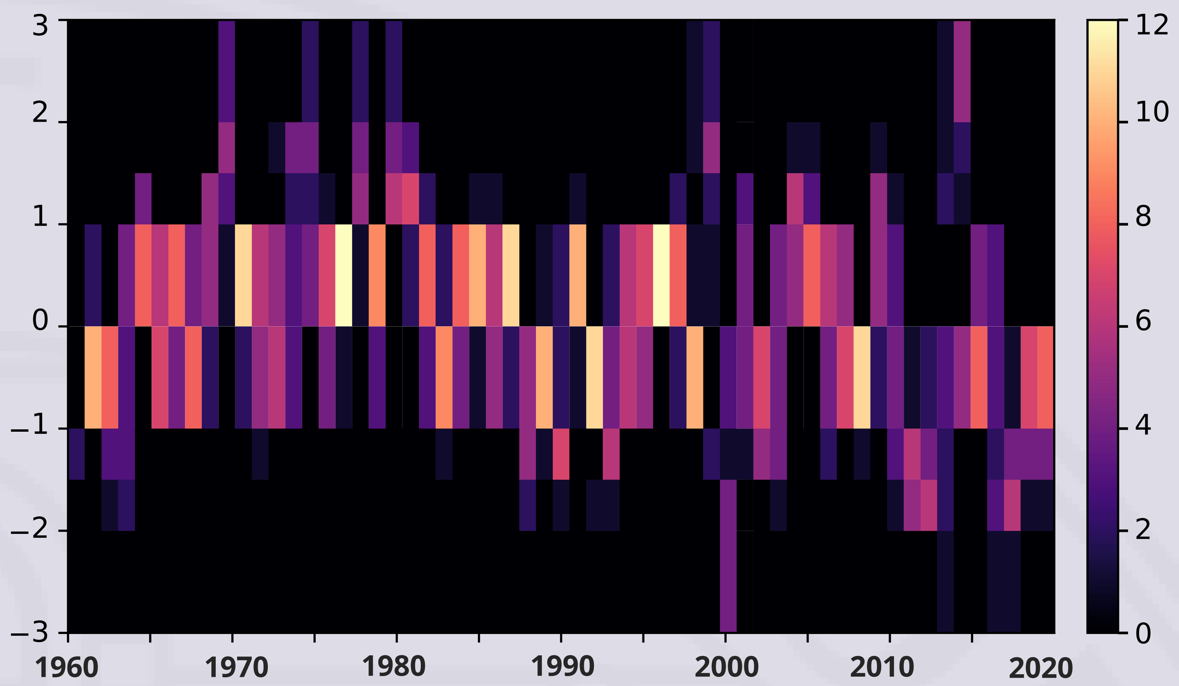

Fig. 2 *Histogram of SPEI12 values over time*

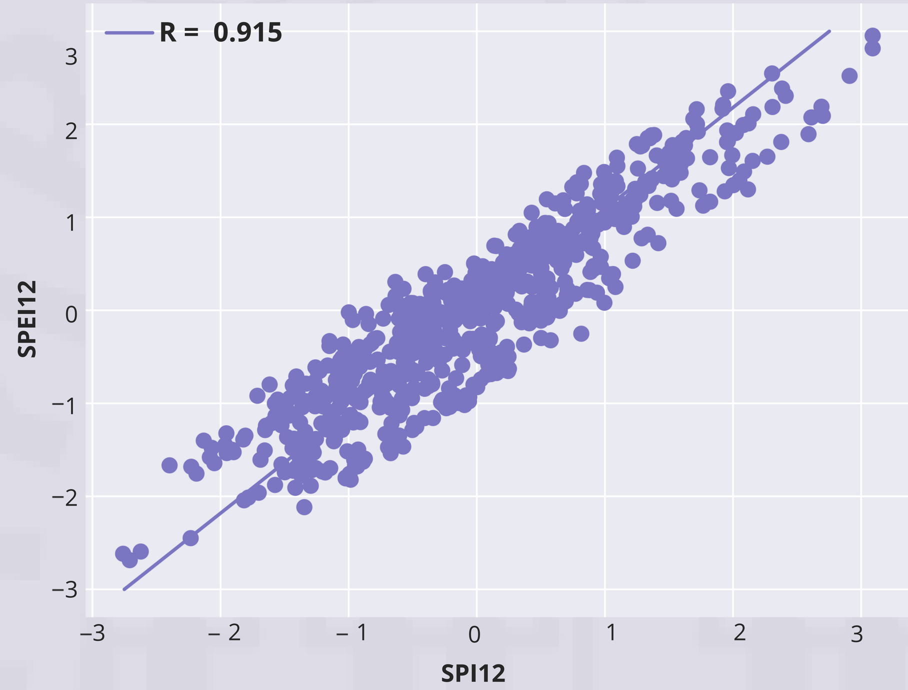

Fig. 3 *Correlation between SPI12 and SPEI12*

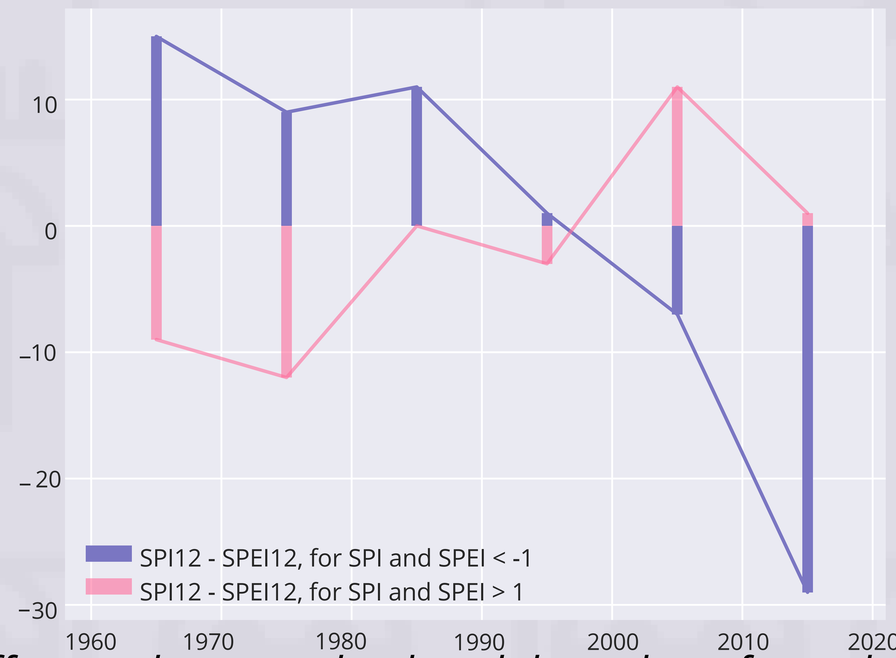

Fig. 4 *Difference between the decadal number of months with both indices greater than 1 and smaller than -1*

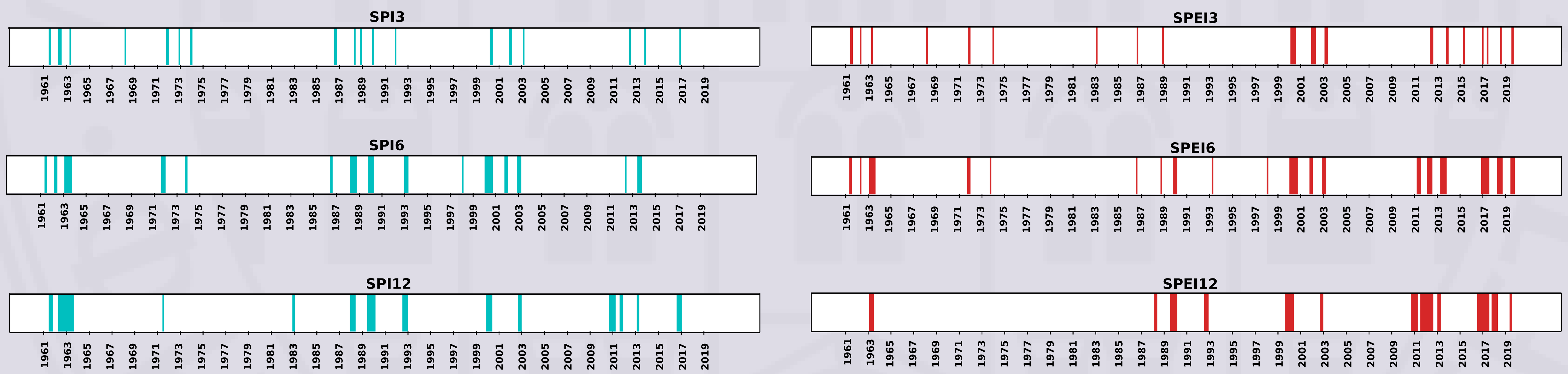

Fig. 5 *Occurrence and length of dry periods according to SPI and SPEI, 3 months or longer (SPI,SPEI < -1)*

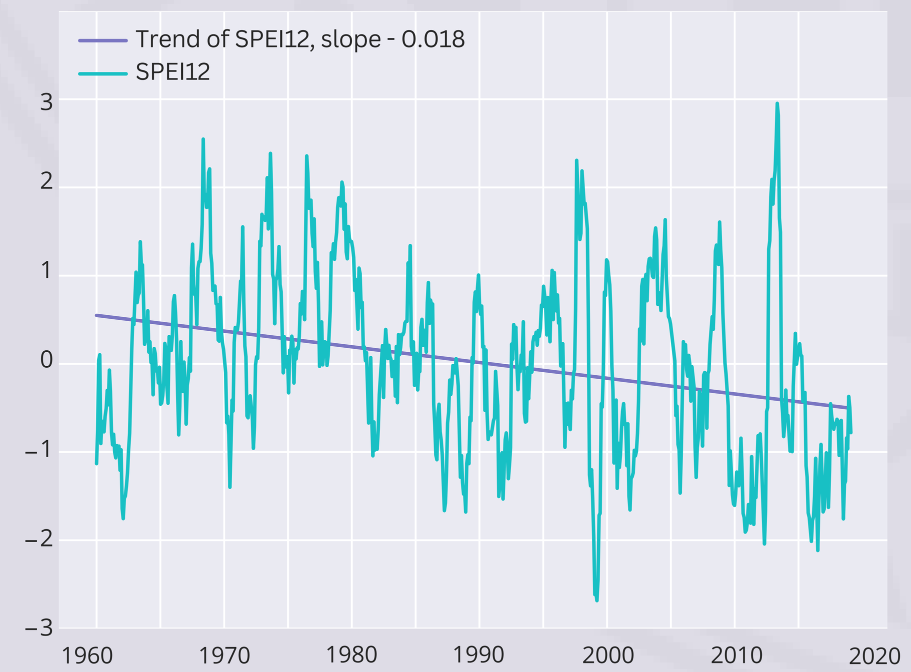

Fig. 6 *Trend of SPEI12 values over the time period of observation*

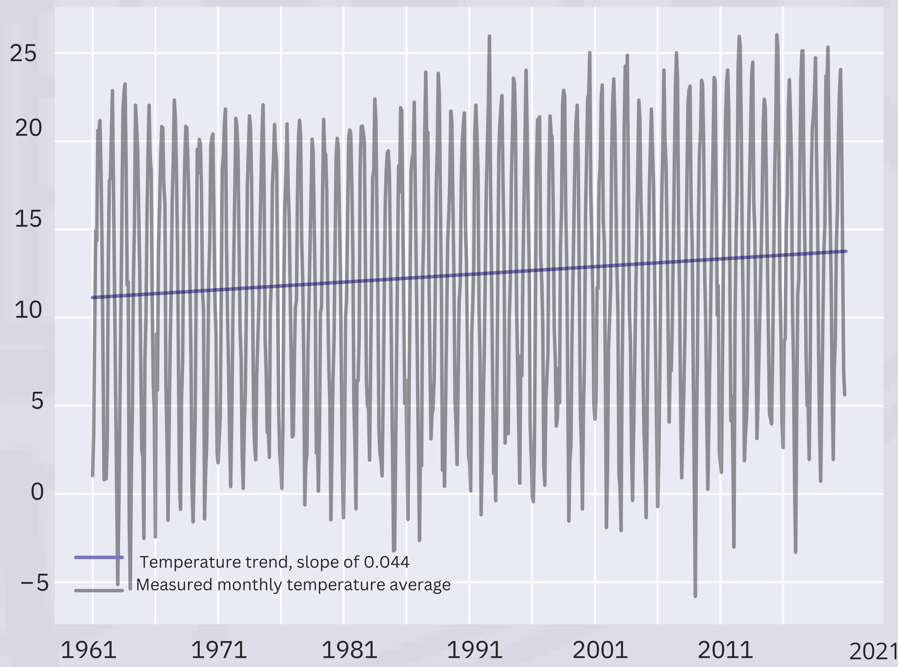

Fig. 7 *Trend of the average monthly temperature for the time period of observation*

4. Conclusions

Data clearly reflects different behavior of the two indices, with SPI detecting periods of rainfall deficit, and SPEI detecting rainfall deficits paired with warmer periods. The trend of rising temperatures in the time period of interest affects SPEI via the value of potential evapotranspiration, which is itself a function of temperature. Thus, longer and more frequent drier conditions detected in the recent time period align with this temperature increase. When existing dry periods align with hotter temperatures, their effects are amplified.

Reliance only on SPI in agrometeorological evaluations and forecasts may lead to misleading conclusions and under-representation of dry conditions in modern times. Inclusion of temperature in the evaluation could more faithfully represent soil water availability. This is especially true when calculating the index for a longer time period (ie a climatological period of 30 years). Also, if forecasts of future index values are to be more accurate, taking into consideration the effects of climate change on the Balkan region,[6] temperature cannot be left out.

References

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