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DROUGHT MONITORING IN SOUTHEASTERN ROMANIA BASED ON THE COMPARISON AND CORRELATION OF SPEI AND SPI INDICES

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Abstract

The main aim was to assess the drought phenomena by comparing two relevant indicators i.e., the standardized precipitation index (SPI) and the standardized precipitation evaporation index (SPEI) using long time series of precipitation and temperature starting from 1961 up to 2020 gauged and validated in the land monitoring system of the Ialomita district located in the southeast of Romania at Grivita station. The obtained results suggested that SPEI can provide better insights regarding the drought phenomena concerning the occurrence of drought events and trend estimation. In the next years, drought events are expected to rise in frequency, duration, and intensity. In our opinion, it would be necessary to exceed the prevailing use of the SPI to assess the drought phenomena and improve the environmental monitoring systems to have robust data both of rainfall and temperature in a high number of gauging stations that could be utilized also for a spatially distributed evaluation of SPEI index.

Key words: *climate trend, drought indices, Grivita meteorological station, Ialomita district, SPEI-SPI correlation.*

INTRODUCTION

In the last decade, large areas of Europe experienced a persistent deficit of precipitation from winter to summer. Higher-than-average temperatures combined with this deficit, led to severe to extreme droughts more frequently. These droughts significantly affected various European regions causing severe socio-economic impacts on sectors such as agriculture and on the natural systems (European Commission, Copernicus Climate Change Service, 2022; Casadei et al., 2020; Vicente, 2022). Short-term drought effects can also include lower water levels in lakes and reservoirs and consequent deterioration of water quality (Di Francesco et al., 2023; Çetin, 2023).
The standardized precipitation index (SPI), first developed by Mckee et al. (1993), was proposed by the World Meteorological Organization and the Lincoln Declaration on Drought as a reliable standard index for worldwide application (Hayes et al., 2011). Later on, it was selected in the set of common indicators for water scarcity and drought by the Water Scarcity and Drought Expert Group of the European Commission (Faergemann, 2012). Considering global climate warming, air temperature variations are expected to become particularly the new primary driver of droughts, at the level of high-latitude cold catchments.
Assessment of the evapotranspiration (ET) processes is a key element for providing updated information for water resources management, weather forecasts, climate studies, agriculture, and other applications (Dunea et al., 2021; Casadei et al., 2021). Easy access to reliable estimations of ET is important within these sensitive domains. ET has an important role in examining and forecasting drought occurrence and drought severity both at local and global scales. Consequently, ET should be used together with precipitation in developing reliable drought indices (Khoshnazar et al., 2022).
Vicente-Serrano et al. (2010) developed the *standardized precipitation evapotranspiration index* (SPEI) based on SPI by including the temperature in its computation with input parameters such as the monthly precipitation and temperature data. A complete dataset is

required with no missing months in the time series.

SPEI has been employed in different areas of the world to analyze the drought incidence, its characteristics, and its relationship with water scarcity. The utility of SPEI in drought studies is demonstrated, but the requirement of a complete dataset for both temperature and precipitation can be challenging and may limit the use of SPEI due to data unavailability.

In this context, the present study aims to explore the correlation SPEI vs. SPI using long time series (from 1961 to 2020) recorded at Grivita station in Ialomita district, Romania, an area located in a plain with temperate-continental climate characterized by very hot summers and cold winters, and a relatively large annual and diurnal thermal amplitude and by precipitation in small amounts (the average annual thermal amplitude is 25.1°C, and the maximum amplitude exceeded 70°C). The *SPEI-SPI correlation* is expected to provide useful insights to overcome the potential lack of temperature dataset.

Ialomita district is one of the most important agricultural regions for cropping maize, and sunflower in Romania. Therefore, the presented results may provide useful outcomes for future assessments and better management in these regions and elsewhere, also improving the agrometeorological forecasting. So far, this type of study has been conducted by a small number of researchers with incomplete results, and thus the knowledge is still at the beginning (191 results in the Web of Science database using the string "*SPEI SPI correlation*").

For Romania, only two papers were retrieved with case studies for the Carpathian Region (Spinoni et al., 2013) and Eastern Romania (Minea et al., 2022). Furthermore, the European Drought Observatory mentions SPEI as a widely-used drought index, but it produces updated data only for the SPI index (https://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1010).

The current study is the first applied for a region located in the South of Romania by employing long time series derived from data collected at a gauging station (60 years period), rather than available gridded datasets, to have a more reliable indication for the study of climatic trends and the comparison between SPI and SPEI.

MATERIALS AND METHODS

Study area

The Ialomita district (Muntenia region, Romania, Figure 1) is located in the plain and it has a temperate continental climate with excessive nuance that is characterized by the presence of hot summers and very cold winters, with a high thermal amplitude of 76.5°C (the absolute minimum was -32.5°C in Armășești, Jan. 25, 1942, and the absolute maximum until +44°C, Amara, in August 1951), low precipitation and unevenly distributed both in time and territory and an atmospheric circulation predominantly from the east and northeast.

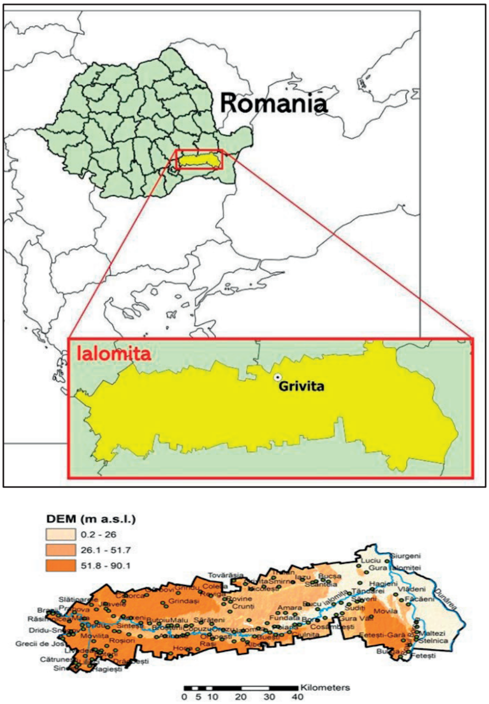


Figure 1. Area of study in southeastern Romania: Ialomita District with Grivita meteorological station; Altimetry of the Ialomita District (Romania) based on the EU-DEM v1.1 (https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1.1/view) and the Grivita station

Among the characteristic climatic phenomena stand out frost and blizzards, in the cold period, and drought, dew, and hail, in the warm periods of the year. The Grivita meteorological station (27.294E; 44.748N; 45 m a.s.l.) is representative in the area.

Datasets

The computation for both SPI and SPEI requires at least thirty years of data to achieve credible results, and consequently longer samples can assure improved accuracy in drought estimations (Wu et al., 2005). Usually, SPEI and SPI indices are computed at different time scales from 1 month to 48 months allowing the estimation of the drought's impact on various types of water resources. For example, agricultural droughts, mainly conditioned by soil moisture, are typically defined at a time scale shorter than hydrologic droughts, linked to groundwater, streamflow, and reservoirs (Svoboda et al., 2012). There are seven SPI classes (generally considered valid also for the SPEI index) according to WMO's SPI User Guide from *extremely wet* to *extremely dry* with various probabilities of occurrence. In this study, we have selected an annual time period for presentation (SPI12 and SPEI12) to provide a clear general image of the drought trends. The monthly rainfall data used for SPI (SPEI) calculation has been obtained as cumulative daily rainfall, and the mean, maximum, and minimum monthly temperature as an average of mean, maximum, and minimum daily temperature, respectively.

Computations and data analysis

The selected indices were calculated in the R-environment using the SPEI package https://cran.r-project.org/package = SPEI.

In this study, the drought events were retrieved using the run theory as described in Yevjevich (1967). SPI (SPEI) values were characterized as time series functions and specify the intensity (I) of drought (or wet) conditions. Continuous negative values of the index under the threshold value SPI (SPEI) = 0 indicate that a drought event occurs (Sharafati et al., 2020).

Trend detection was performed using the Mann-Kendall (MK) method (Mann, 1945; Kendall, 1975), which is a non-parametric test to analyze the trend in time series, and the Innovative-Sen trend (IST) method (Sen, 2012).

The Pearson correlation coefficient r was computed to evaluate the correlation.

RESULTS AND DISCUSSIONS

Precipitation and temperature: the trend detection

The annual cumulative precipitation (ACP) was between 287.1 mm and 775.9 mm and the annual average temperature (AAT) ranged between 9.3°C and 13.1°C at Grivita station. Table 1 provides the slope of linear regression (m), the standardized variable Z_{MK}, slope s, and the correspondent confidence limit determined using the IST test.

First, considering the linear regression slope, Grivita presents a decreasing tendency of ACP (m = -1.24) and an increasing trend of AAT (m = 0.0308). The MK test evaluated the trend of the ACP of Grivita not significant for a significance level of 5%. Differently, the increasing trend of AAT was evaluated both by the MK test (Z_{MK} = 4.95) and IST method as significant, for the same significance level.

It is possible to conclude that, both for precipitation and temperature, the Grivita dataset presented a monotonic trend, decreasing for precipitation and increasing for temperature.

SPI (SPEI) 12 trend

The tendency of the annual time series of SPI (SPEI) 12 is shown in Figure 2 where, in the same chart, both the indices' temporal series (the red line for SPI and the blue line for SPEI) are represented.

For SPEI (SPI) 12, Figure 3 (a) illustrates the linear regression analysis with the correspondent regression equation, and Figure 3 (b) the results of the IST method.

Table 2 allows the comparison of the results of regression analysis, MK, and IST methods. First, it is possible to observe that the slope of linear regression m is negative for both indices, but the value of SPEI is more negative than SPI. MK test provides a significant negative monotonic trend only for the SPEI 12, not for the SPI 12; differently, the IST method provides a significant negative monotonic trend both for SPI 12 and SPEI 12.

Comparing the trend of SPI 12 and SPEI 12, it is clear that SPEI shows generally a decreasing tendency more significant than SPI, both in terms of regression slope m and IST test results.

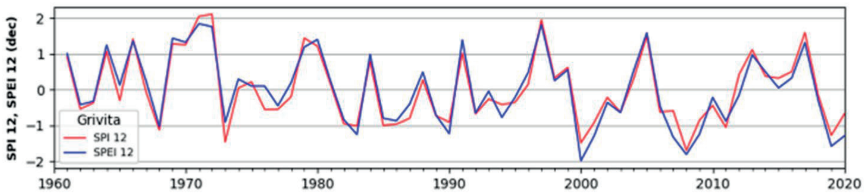
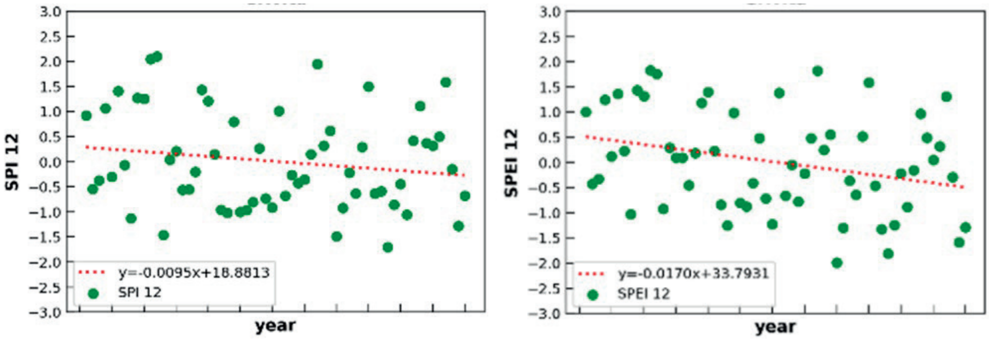
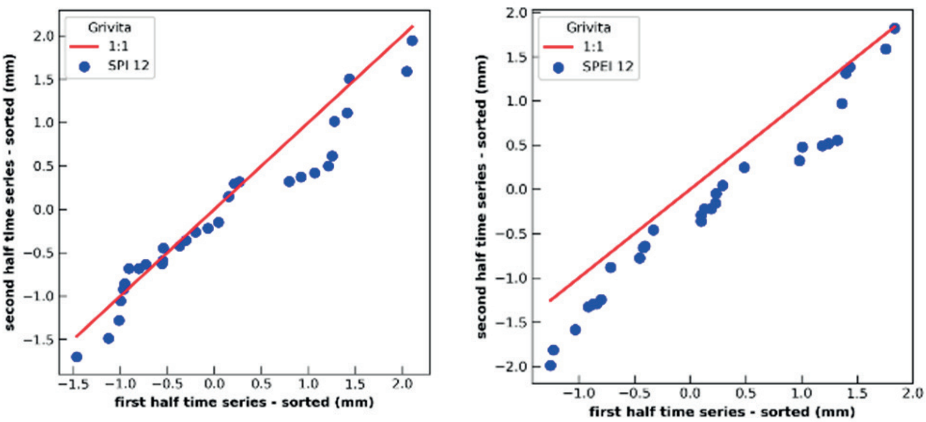


Figure 2. SPI 12, SPEI 12 time series recorded for Grivita station between 1961 and 2020



a)



b)

Figure 3. Linear regression (a); IST method - SPI 12 and SPEI 12 (b)

Run Test

The run test has been used to identify the drought features based on the SPI (SPEI) 12-time series: in particular, the first half part of the time series (first period: FP - 1961-1990) and the second half part (second period: SP - 1991-2020) have been considered.

In Table 3, drought events have been characterized using the following parameters: number of events, maximum, average, and standard deviation (SD) of the duration expressed in years, maximum peak and severity value, and their occurrence.

In Figure 4, the boxplot charts of peak and intensity magnitudes of SPI (SPEI) 12 for each drought event, in the first and second periods, are shown. It is possible to observe that both the median and average peak and intensity are always lower in the first period than in the second period.

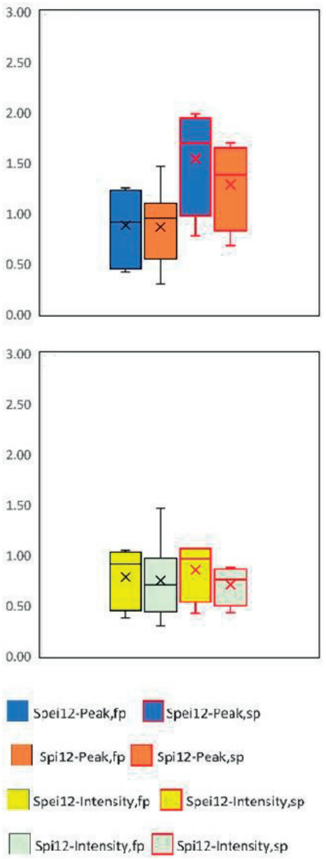


Figure 4. Boxplot of the absolute value of peak and intensity for SPI(SPEI) 12 for Grivita station. Boxplot elements: box = values of 25th and 75th percentiles; horizontal line = median; cross = average; whiskers limit = minimum/maximum value; interquartile range (IQR) = difference between 25th and 75th percentile

Then, in particular, in the second period, it is clear that the trend of the median (average) of SPEI overcomes the one of SPI.
Previous considerations are according to the trend test analysis of SPI (SPEI) and can be because SPEI, which considers the temperature, can catch, better than SPI, the increasing tendency of drought phenomena.
In Figure 5, the peak magnitude values derived from run test analysis have been arranged in four classes, from 0 to 3, following the WMO guidelines (Svoboda et al., 2012): "0" identifies the normal level, "1" the moderately dry, "2" the severely dry and "3" the extremely dry level.
First, we observe that SPEI gives a percentage of critical events (falling in the second and third class) higher than SPI (27% against 8%); then, only for SPEI, the percentage of critical events that fall in the first period is lower than in the second period (9% against 27%) whereas this trend is not confirmed for SPI (25% against 8%).

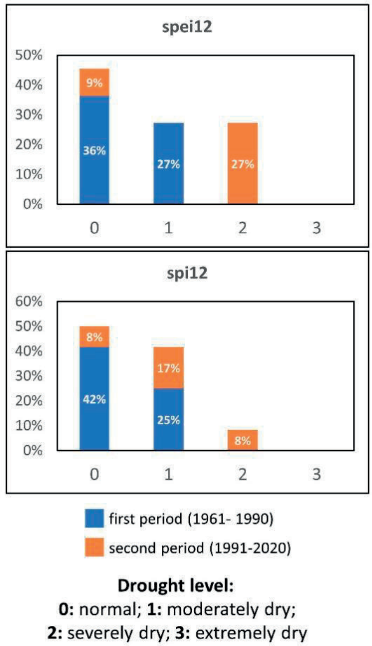


Figure 5. Distribution of drought levels (WMO, 2012) in the first and second periods (SPI 12, SPEI 12)

SPEI and SPI correlation

Hereafter, we consider the relationship, based on the method of least squares, between SPEI and SPI indices, to compare the eventual change of trend in the last sixty years.
The linear correlation between SPI and SPEI 12 is shown in Figure 6. In each graph, the linear regression equation and the determination coefficient (R^2) are indicated, which specifies how well the regression equation explains the relationship between the variables.
The goodness of fit of the linear regression can be also expressed by the Pearson correlation coefficient r, with $r = \sqrt{R^2}$.
In Table 4, it is possible to observe that r is always relatively high; however, there is a certain difference between the first and the second periods: in fact, r is lower in the second period than in the first (0.961 against 0.973).

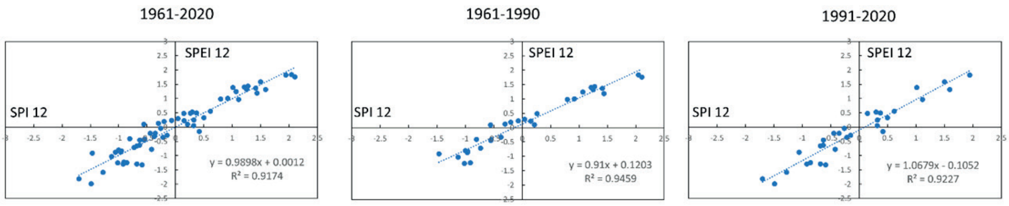


Figure 6. Relationships related to the drought trends: SPEI 12-SPI 12 correlations

Table 1. Linear regression, MK test and IST method applied to annual cumulative precipitation and average annual temperature at the Grivita station

Station	**Variable**	**Linear regression** (slope **m**)	**Mann Kendal test** (Standardized variable $\mathbf{Z_{MK}}$)	**IST - trend slope**	
				Confidence limit $CL_{1-\alpha}$	**Trend slope (s)**
Grivita	annual cumulative precipitation (ACP)	-1.24	-0.86	±0.256	-0.743*
	average annual temperature (AAT)	0.0308	4.95*	±0.002	0.031*

**Statistically significant at a 5% level*

Table 2. SPI, SPEI 12 (linear regression, Mann Kendall test, IST)

Station	**Indicator**	**Linear regression (slope m)**	**Mann Kendall test (Standardized variable $\mathbf{Z_{MK}}$)**	**IST - trend slope**	
				Confidence limit $CL_{1-\alpha}$	**Trend slope (s)**
Grivita	SPI 12	-0.0095	-0.86	±0.00195	-0.00537*
	SPEI 12	-0.0170	-1.96*	±0.00120	-0.01279*

**statistically significant at a 5% level*

Table 3. Characterization of drought events for Grivita time series: SPI12, SPEI12

Parameters	Grivita			
	SPI12		SPEI12	
	FP	SP	FP	SP
Droughts number	8	4	7	4
Max droughts duration (years)	3	6	3	7
Average droughts duration (years)	2.00	4.25	1.71	4.50
SD droughts duration (years)	0.76	1.26	0.76	1.73
Max Peak Value	1.70		1.99	
Max Peak Value - occurrence	2008		2000	
Max Severity Value	5.28		6.10	
Max Severity Value - occurrence	2006-2011		2006-2012	

Table 4. Correlation SPI-SPEI: r values

SPI 12 - SPEI 12		
r12	**r12-1**	**r12-2**
1961-2020	**1961-1990**	**1991-2020**
0.958	0.973	0.961

CONCLUSIONS

The study aims to compare the efficacy of SPI and SPEI indices in monitoring drought events in southeastern Romania areas, in particular verifying the correlation between the two indicators and the consequential possibility of using SPI instead of SPEI. In fact, SPI, based only on precipitation, requires less availability of data concerning SPEI, which needs the estimation of evapotranspiration.

For this purpose, we have considered a long-time series at Grivita Station (Southeastern Romania) of precipitation and temperature data, gauged and validated through the environmental monitoring systems.

The analysis of SPI (SPEI) 12 shows a general decreasing tendency of the indices both in terms of regression slope, MK, and IST test results. In particular, this trend was confirmed by the run theory applied to the first part (1961-1990) and second part (1991-2020) of the SPEI time series: in fact, the percentage of drought events that fall in the first period is lower than in the second period; moreover, it is observed that SPEI gives a percentage of critical events higher than SPI. Finally, the possible estimation of SPEI from

SPI has been correlated to the Pearson coefficient: its value is generally high, but it tends to decrease passing from the first part to the second part of the time series.

This could be explained by the increase in the mean temperature in the last thirty years, which negatively affects the quality of the correlation between the two indices.

Given this, it could be convenient to overcome the prevailing use of the SPI index to assess droughts, improving the environmental monitoring systems to have reliable data both of rainfall and temperature in a high number of gauging stations.

An increased number of stations could be also useful for a spatially distributed evaluation of the SPEI index.

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