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A comparative assessment of meteorological drought in the Tafna basin, Northwestern Algeria

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Abstract: The drought ranked first in terms the natural hazard characteristics and impacts followed by tropical cyclones, regional floods, earthquakes, and volcanoes. Drought monitoring is an important aspect of drought risk management and the assessment of drought is usually done through using various drought indices. The western region in Algeria is the most affected by the drought since the middle of the 70s.The current research focuses on the analysis and comparison of four meteorological drought indices (standardized precipitation index – *SPI*, percent of normal index – *PN*, decile index – *DI*, and rainfall anomaly index – *RAI*) in the Tafna basin for different time scales (annual, seasonal, and monthly) during 1979–2011. The results showed that the *SPI* and *DI* have similar frequencies for dry and wet categories. The *RAI* and *PN* were able to detect more drought categories. Meanwhile, all indices have strong positive correlations between each other, especially with Spearman correlation tests (0.99; 1.0), the meteorological drought indices almost showed consistent and similar results in the study area. It was determined in 1982 as the driest year and 2008 as the wettest year in the period of the study. The analysis of the trend was based on the test of Mann–Kendall (MK), a positive trend of the indices were detected on a monthly scale, this increasing of indices trend represent the increasing of the wet categories which explains the increasing trend of the rainfall in the last 2000s. These results overview of the understanding of drought trends in the region is crucial for making strategies and assist in decision making for water resources management and reducing vulnerability to drought.

Keywords: drought, meteorological drought indices, Tafna basin, trend analysis

INTRODUCTION

Drought is an inevitable and recurring feature of the global water cycle [Farahmand, Aghakouchak 2019], and it is expected to affect as many as one-third of the world's population [Swetalina, Thomas 2016], and a large proportion of the agricultural sector, especially in arid and semi-arid regions in Mediterranean [Kumar 1998; Tigkas, Tsakiris 2014], which is already suffering from stress and water availability [Ma *et al.* 2015] due irregularity of rainfall in time and space [Shahabfar, Eitzinger 2013] and expected to be worsen in future due to climate change [IPCC 2014].

Drought is one of the most damaging natural hazard and can be classified to four categories. Drought meteorological characterizes a broad range of climatic situations related to either negative departure of rainfall from the normal rainfall over a period of time consequent to the high temperature and the evapotranspiration, these are considered as significant factors of controlling the formation and persistence of the condition of drought, and usually appears before other types of drought (agricultural, hydrological, socio-economic drought) [Bazrafshan, Khalili 2013; IPCC 2014; Lloyd-Hughes, Saunders 2002; Marengo *et al.* 2011; Soo Jun *et al.* 2011; Swetalina, Thomas 2016; Vogt, Somma 2000].

Several studies have used drought indices as drought monitoring tools at different parts of the world to describe the droughts quantitatively and make the decision on estimations of the characteristics of a drought period and their consequences upon the hydrological cycle [Afzali *et al.* 2016; Al-Timimi, Osamah 2016; Asefjah *et al.* 2014; Bagheri 2016; Dogan *et al.* 2012; Shah *et al.* 2015; Tsakiris *et al.* 2013]. There are indicators disaggregated by the type of drought [Guttman 1998; Wilhite, Glantz 1985], and classified into four main types: (a) meteorological drought, related to precipitation deficit which cause decreases in water supplies of a region over a period of time; (b) hydrological drought, defined as a deficit in surface water storage or groundwater causing reductions in water uses and effect to water resources management system; (c) agricultural drought, deficit in soil moisture and the consequent to crop failure at a particular period; and has no reference to stream flow; meteorological drought, hydrological drought and agricultural drought are also considered as environmental droughts whereas; (d) socio-economic drought is deficit of water supply for socio-economic purpose, and it can be considered as water resources droughts [Azarakhshi *et al.* 2011; Passioura 2007; Wilhite, Glantz 1985; WMO 2006].

Drought is a frequent climate that determines its precision and the difficulty of studying the various dimensions of it. It can be described by three factors: severity, duration, and frequency of occurrence [Soleimani Sardou, Bahremand 2014; Tsakiris *et al.* 2007; Wilhite 2000]. It has been observed that droughts have increased in magnitude and frequency, over the last few decades around the world. Droughts affect almost all the components of the hydrological cycle beginning with the precipitation factor that experienced a long period of the deficit, which has negative influence in hydrological drought of the streamflow and resulted in deficit in storage for surface water and groundwater [Beran, Rodier 1985; Sahnoune *et al.* 2013; Tsakiris *et al.* 2013]. There is no single definition of drought and it is difficult to determine its onset and termination. However, there are several drought indices developed to measure and monitor different types of droughts which is related to some of the cumulative effects of a prolonged and abnormal moisture deficiency such as standardized precipitation index (*SPI*), surface water supply index (*SWSI*), etc. However, several of the drought indices have limitation in the application in order to monitored the drought condition due to climate condition as well the time step, and thus must addressing more than one index [Jain *et al.* 2015; Morid *et al.* 2006]. However, identify various indicators of drought, and tracking these indicators provides the assimilation for thousands of data on rainfall, streamflow, and other water supply indicators, more useful than raw data for decision making and crucial means of monitoring drought. Drought indices are usually calculated, either by applying manually the corresponding equations, or by using tools, that provide a comprehensive assessment and give a better perspective for outputs [Tigkas *et al.* 2015].

Algeria is one of the countries, which has experienced several drought years, with high variability in annual rainfall [Habibi *et al.* 2018] with a reduction of 10% since the end of the 1970s [Sahnoune 2013] this may affect the water mobilized in dams and groundwater. Particularly affected is the western north region [Meddi, Hubert 2003; Meddi, Meddi 2009], where experienced deficits in rainfall from 12% to 20% [Medjerab, Henia 2005]. This region suffered by drought years [Meddi *et al.* 2013] with the return of rising in rainfall between 2001 and 2007 [Khoualdia *et al.* 2014]. And the severe/extreme droughts have return periods of around 36 [Halwatura *et al.* 2017; Lazri *et al.* 2015; McCarthy 2001].

Numerous studies have been conducted to analyse and identify drought condition from different parts of the world as for example, the analysis of the hydrological drought over 36 years (1972–2007) in Ghataprabha River basin, India, indicated moderate drought between 1986–1988 and 2001–2005 [Pathak *et al.* 2016]. Whereas in semi-arid areas, the studies that were conducted in different regions in Iran for drought monitoring showed that the region has been suffered from a range of moderate to extreme droughts [Akbari *et al.* 2015; Morid *et al.* 2006; Zarei *et al.* 2017]. The studies in the Mediterranean area, such as in Greece showed that the indices identify the same drought events which appears in the four study for 45 years (from 1956 to 2001) [Kanellou *et al.* 2008]. While the study in the Balearic Islands in Spain from 1974 to 2014, showed two drought episodes between 1988–1991 and 1999–2001 [Lorenzo-Lacruz, Morán-Tejeda 2016]. Further, in the south Mediterranean area, the researches of Abdelmalek and Nouiri [2020] and Gader *et al.* [2020] in Tunisia region explored the pattern of historical droughts and characterize drought variability based on meteorological drought results, which demonstrated that Tunisia has experienced several multi-year droughts (from 3 to 7 years) with different severities, and is marked by a significant spatio-temporal variability of drought, with varying extreme wet and dry events. In the Inaouen region of northern Morocco, the analysis of the droughts showed that the frequency of episodes of drought varied according to the time scale considered [Boudad *et al.* 2018]. Similar researches in northern of Algeria studied the drought behaviour in the time series and the results showed that the severe/extreme drought increases considerably rising from the probability of probability of drought occurred through a Markovian approach is 0.2650 in 2005 to a stable probability of 0.5756 in 2041 [Lazri *et al.* 2015].While in the northeast region of the country were studied for the variability and trends in annual rainfall data for the period between 1970 and 2011 and it was found that the important fluctuation where experienced a long dry period with a moderate severity followed by a long wet period and a significant increasing rainfall trend [Khezazna *et al.* 2017]. The studies in northwest of Algeria identified that the region had suffered from a severe drought especially after 1970's and multi-year drought, and this information may provide scientific support for managing drought situations [Djellouli *et al.* 2016; Habibi *et al.* 2018; Khoualdia *et al.* 2014; Meddi *et al.* 2013; Mrad *et al.* 2018b].

The main objective of this study is a comparative analysis of four meteorological drought indices: (i) the standardized precipitation index (*SPI*), (ii) the percent of normal index (*PN*), (iii) the decile index (*DI*), and (iv) rainfall anomaly index (*RAI*). No index is ideal and/or universally suitable. The choice of indices for drought monitoring in a specific area should eventually be based on how commonly used these indices to determine the drought and the quantity of data availability [Azarakhshi *et al.* 2011; Bouabdelli *et al.* 2020; Dikici 2020; Morid *et al.* 2006]. A common feature of the selected indices is that they all are calculated using only rainfall data at different time scales and allows the analysis of different drought categories. In order to assess the performance of these indices in the Tafna basin

(Northwest of Algeria) reflecting the amount of rainfall, which represents the water resources availability and its relation to the several activities related to water [Bayissa *et al.* 2015; Tabari *et al.* 2012]. Furthermore, *SPI* found as a highly valuable estimator of drought severity [Keyantash, Dracup 2002] and was proven superior to Palmer drought severity index (*PDSI*) [Guttman 1998; Paulo, Pereira 2006], and other rainfall based indices [Dogan *et al.* 2012; Hänsel *et al.* 2016; McKee *et al.* 1993; Morid *et al.* 2006; van Rooy 1965]. These indices were the most used in the north of Mediterranean region, while the *DI* index defined as able to quantify both dry and wet cycles [Morid *et al.* 2006], as well as *SPI* and may assessing droughts when used with many time steps (short term) in arid/semi-arid regions. The analysis of the study of Barua *et al.* [2011] showed that *SPI* had the same raw score for the transparency criterion and were less transparent than *PN* or *DI*, with *PN* having the highest transparency score and was also found as the most irrelevant *DI* to other indices [Dogan *et al.* 2012]. The *RAI* offers a higher degree of transparency and tractability and demands a lower degree of sophistication than the *SPI* with regard to the evaluation criteria for drought indices as proposed by Keyantash and Dracup [2002]. In principle, the *RAI* may be calculated on the same time scales as the *SPI* and is similarly robust.

MATERIALS AND METHODS

STUDY AREA

The Tafna basin (Fig. 1) is a transboundary basin covering an area of 7245 km^2. The biggest part of its area is located in the Northwest of the Algerian territory (Wilaya of Tlemcen) and the upper part on the territory of Morocco. According to the new structure of hydro geological units in Algeria, the Tafna basin belongs to the entire Oranie–Chott–Chergui [Bouanani 2004].

It extends between 1° and 2° west longitude and 34°5' and 35°3' north latitude [Bouanani 2004] and consists of eight sub basins in which two are located upstream in the Moroccan territory (2007 km^2 representing around 27.7% of the total area) [Ketrouci *et al.* 2012]. The Tafna basin features very rugged terrain with an average and maximum altitude of 780, 1800 m a.m.s.l. (Fig. 1a) which is dominates the regions of the plains of Maghnia, Hannaya and Sidi Abdelli in northern area of the basin. It has a 170 km long stream with its source in the Tlemcen Mountains, i.e., region of Sebdou and Isser Wadi and Maghnia region (Mouillah Wadi effluent from the Moroccan part) [Bouanani 2004]. The geology of Tafna basin is divided into two zones: the upstream part characterizes by Jurassic rocks rich in limestone and dolomite, and the downstream part by Miocene marls covered by recent alluvium belonging to the Quaternary [Taleb *et al.* 2004]. The upper basin mainly occupies forests, sparse vegetation, and pasture, with irrigated crops occupying the rest [Bouanani 2004]. The hydrographical network of the Tafna basin consists mainly by two river arteries: the Wadi Tafna in West and the Wadi Isser in the East that has its source in the Tlemcen Mountains. The mean annual rainfall is 469 mm, computed over a period of 66 years (1939–1940 to 2004–2005) [Ghenim *et al.* 2010]. The climate regime is characterized by a semiarid Mediterranean climate with a relatively cold and rainy winter, with maxima in December, January and February and a hot and dry summer. The study area system is experience high spatial and temporal variability of total rainfall major land use and soil types of the study area [Meddi *et al.* 2010; 2013].

DATA AND METHODS

In the current research, historical records of the rainfall data were acquired from the National Agency of Hydraulic Resources (Fr. Agence Nationale des Ressources Hydriques – ANRH) for the period 1979–2011. The daily data were collected from nine climate stations (Sebdou, Beni Bahdel, Khemis, Hennaya, Djbel Chouachi, Chouly, Merbeh, Ouled Mimoun, and Sidi Benkhala) located in different parts of the Tafna basin, as shown in Table 1 and Figure 1b. The homogeneity test of Lee and Heghinian detected two significant break dates for an annual time scale in rainfall, i.e., in 1980 for Sebdou, Beni Bahdel, and Hennaya stations and the rest of the stations in 2007. For the single station Djbel Chouachi, a break date was revealed in 1999 with Pettitt

Table 1. Rainfall station in the Tafna basin

No.	Station	Code of station	Longitude (W)	Latitude (N)	Elevation (m a.s.l.)	Annual average rainfall for period 1979–2011 (mm)
1	Sebdou	16-04-01	1°33'	34°65'	875	361.8
2	Beni Bahdel	16-04-03	1°51'	34°71'	666	400.4
3	Khemis	16-04-06	1°56'	34°64'	920	399.3
4	Hennaya	16-05-16	1°39'	34°92'	515	378.3
5	Djbel Chouachi	16-05-18	1°50'	34°94'	110	278.7
6	Chouly	16-06-01	1°14'	34°83'	700	393.9
7	Merbah	16-06-02	1°17'	34°79'	1 100	375.2
8	Ouled Mimoun	16-06-07	1°03'	34°90'	705	330.6
9	Sidi Benkhala	16-06-10	1°05'	35°03'	430	340.5

Source: own elaboration.

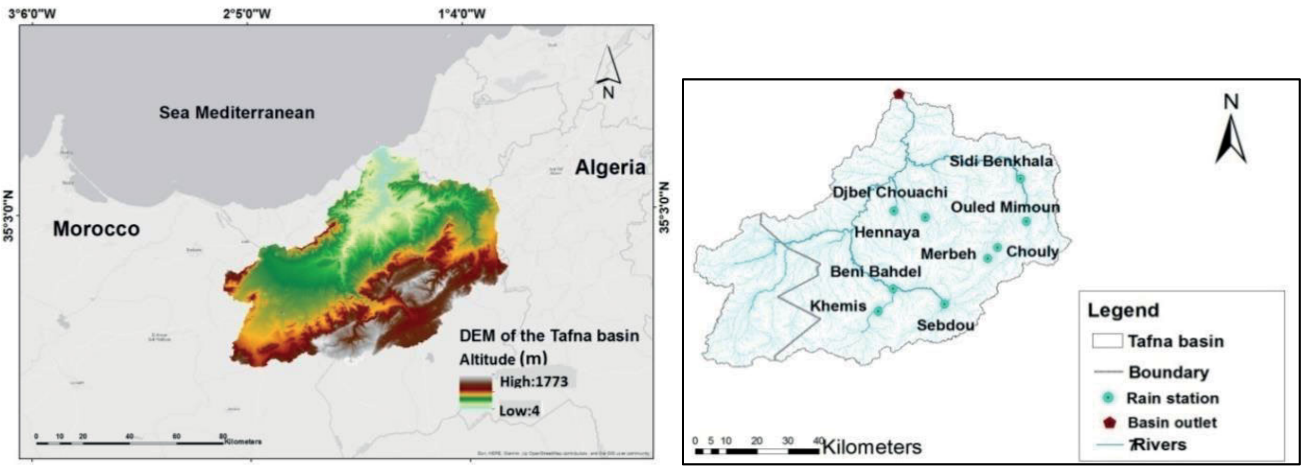

Fig. 1. Study area: a) digital elevation model, b) spatial distribution of rainfall stations in the Tafna basin; source: own elaboration

and Buishand tests due to the time series are not homogeneous, whereas the trend test showed no significant trend at the same station, which can be explained by the multi breakpoint at the rainfall time series not indicating any increase or decrease of a rainfall trend. The stationarity test Jonckheere–Terpstra confirmed the results of no trend at the Djbel Chouachi station. The normality test of the Kolmogorov–Smirnov showed that the annual rainfall data are following a normal distribution only at the Sidi Benkhala station. Annual rainfall is fitting the normal distribution as per the Shapiro–Wilk test at Sebdou, Merbeh, Sidi Bounkhala, and Ouled Mimoun stations. Monthly rainfall data do not follow a normal distribution for all stations according to both tests [Bougara *et al.* 2020].

The methodology applied in this study is based on four meteorological indices (standardized precipitation index – *SPI*, rainfall anomaly index – *RAI*, decile index – *DI*, and percent of normal index – *PN*) selected for drought monitoring in the Tafna Basin in order to:

(1) Classify the frequency of the drought severity categories (or humidity) using a percentile approach for magnitude category thresholds method which enables to easily interpret the drought magnitude. It should be noted that drought classification system is flexible, and easy to incorporate in new technologies, and provide a consistent and replicable standard for drought classification based on the values of the drought indices for three-time scales (annual, seasonal, and monthly), where droughts are generally slow to emerge and slow to recede, and usually changes incrementally during an period, some region experience drought impacts for months or years, for this reason detecting of drought indices in varying durations have been considered, which being used to assess short- and long-term drought severity separately.

(2) Determine the correlations between *SPI* and other indices (*RAI*, *DI*, *PN*), using the correlation coefficients of Pearson and Spearman. *SPI* is considered for analysing its correlation with other three indices because it is most often used as the measure in the drought analysis [Guttman 1998; Hayes *et al.* 1999], and most applied index to analyse meteorological drought in the northwest region of Algeria [Adjim, Djedid 2018; Djellouli *et al.* 2016; 2018]. This proves the applicability of the comparison of *SPI* with the rest of the indices that have not yet received much attention in this part of the areas a primary step in the analysis.

(3) Investigate the relationship between the results of each meteorological drought index from all stations at a different time scale using the correlation coefficients of Pearson and Spearman to assess the sensitivity and robustness for each index.

(4) Indicating the trend directions of the drought indices selected in the time series, using Mann–Kendall test, one of the most widely applied test, using Mann–Kendall test, one of the most widely applied test [Bari Abarghouei *et al.* 2011; Boudad *et al.* 2018; Deo 2011; Hänsel *et al.* 2016; Jain, Kumar 2012; Khezazna *et al.* 2017; Kumar *et al.* 2019; Rahman *et al.* 2016] to detect whether the trend is upward or downward of the data during a time period while considering the level of statistical significance [da Silva *et al.* 2015; Gedefaw *et al.* 2018; Kisi, Ay 2014; Mrad *et al.* 2018a].

METEOROLOGICAL DROUGHT INDICES

Standardized precipitation index (*SPI*)

SPI is a widely recognized tool for characterizing and monitoring meteorological droughts McKee *et al.* 1993. Positive *SPI* values demonstrate that greater than mean precipitation and negative values indicate less than mean precipitation. It is a simple index which allows equally checking of wet periods and the dry periods and is based on the long-term precipitation record (longer than 30 years) [Boudad *et al.* 2018; Edwards, McKee 1997]. The available long-term rainfall data is fitted to a probability distribution (e.g. gamma distribution) to calculate *SPI*, which is then transformed to a normal distribution so that the mean *SPI* period is zero [Jain *et al.* 2015; McKee *et al.* 1993]. The equations to calculate *SPI* are as follows, the rainfall data are calculated using the probability density function of the gamma distribution, which is defined as:

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

where: α is a shape parameter, β is a scale parameter and x is the rainfall amount, β and $x > 0$ as:

$$\alpha = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right) \text{ and } \beta = \frac{\bar{x}}{\alpha} \tag{2}$$

where: $\bar{x}$ represents the sample statistic, A the rainfall average as:

$$A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n} \tag{3}$$

$$\Gamma(a) = \int_0^\infty t^{\alpha-1} \mathrm{e}^{-\mathrm{t}}$$

where: Γ(α) is the gamma function, *n* is number of rainfall observations.

The obtained parameters are then used to find the cumulative probability function as:

$$G(x) = \int_0^x g(x)\mathrm{d}x = \frac{1}{\beta^\alpha(\alpha)} \int_0^x x^{\alpha-1} e^{-x/\beta}\, \mathrm{d}x \tag{4}$$

The rainfall dataset may contain zero values since the gamma distribution is undefined for zero rainfall, then the cumulative, *H*(*x*), was calculated as:

$$H(x) = q + (1-q)G(x) \tag{5}$$

where *q* is the probability of zero rainfall.

The cumulative probability is then transformed to the standardized normal distribution random variable with mean zero and variance of one, which is the value of the *SPI*.

Percent of normal index (*PN*)

PN is a simple index to measure the rainfall deficit for a location. The value 'normal' of the index may be calculated for a month, a season or a year, and is considered to be 100%. Analyses using the percent of normal are very effective when applied for a single region or a single season. It is calculated by dividing actual precipitation (P_i) by normal precipitation and multiplying by 100% [Dogan *et al.* 2012; 2006; Shahabfar, Eitzinger 2013]. Rainfall time series should have at least 30 years' worth of data for calculation of the normal period. The range of values for different drought indices are presented in Table 2.

Decile index (*DI*)

The decile index was developed by Gibbs and Maher [1967]. Which is based on ranking the monthly rainfall from the long-term series to construct a cumulative frequency distribution. This distribution is divided into 10 decile parts. The first decile value is the lowest than 10%, while the second decile is between the lowest 10 and 20%, the two above deciles are determined as considerably below normal, and the deciles from 3 to 4 (from 20 to 40%) as below-normal rainfall, while the deciles from 5 to 6 (from 40 to 60%) as near-normal rainfall, and the deciles from 7 to 8 (from 60 to 80%) as above-normal rainfall and the deciles from 9 to 10 (from 80 to 100%) indicate above-normal rainfall [Asefjah *et al.* 2014].

Rainfall anomaly index (*RAI*)

RAI was developed by van Rooy [1965]. It is based on ranking the rainfall value to calculate the positive and negative magnitude of the indices which are computed by using the mean of ten extremes. This index can be analysed on the frequency and intensity of the dry and rainy period [Al-Timimi, Osamah 2016]. The *RAI* offers a higher degree of transparency and a lower degree of complexity than the *SPI* with regard to the evaluation criteria for drought indices [Keyantash, Dracup 2002; Hänsel *et al.* 2016]. The function is defined as:

$$RAI = 3\frac{P-\bar{P}}{\bar{M}-\bar{P}} \text{ if } \mathrm{P} > \bar{\mathrm{P}} \tag{6}$$

$$RAI = -3\frac{P-\bar{P}}{\bar{m}-\bar{P}} \text{ if } \mathrm{P} < \bar{\mathrm{P}} \tag{7}$$

where: $\bar{M}$ is the mean of the ten highest rainfall records for the time series of the study, is the mean of the ten lowest rainfall records for the time series of the study, is the mean rainfall of the time series, and *P* the rainfall for the specific year.

The classification based on the above meteorological four drought indices are given in Table 2.

TREND AND CORRELATION TEST ANALYSIS

The better identification and monitoring of the drought is to compare the correlation between several drought indices and how they respond to the drought categories during the time series of the study for different time steps. Therefore, to evaluate the dependability in determining the correlation between them, the Pearson coefficient and the Spearman's rho correlation will be used, which are well known and widely used internationally. In

Table 2. Classification of chosen meteorological drought indices range

State	Class description	*SPI*	*PN*	*DI*	*RAI*
1	extremely wet	≥2.0	–	1	≥3.00
2	very wet	[1.50; 1.99]	–	2	[2.00; 2.99]
3	moderately wet	[1.00; 1.49]	≥110	3	[1.00; 1.99]
4	normal	[–0.99; 0.99]	]80; 110[	[4; 7]	[–0.99; 0.99]
5	moderately dry	[–1.49; –1.00]	]55; 80[	8	[–1.99; –1.00]
6	severely dry	[–1.99; –1.50]	]40; 55[	9	[–2.99; –2.00]
7	extremely dry	≤–2.00	≤40	10	≤–3.00

Explanations: *SPI* = standardized precipitation index, *PN* = percent of normal index, *DI* = decile index, *RAI* = rainfall anomaly index.
Source: own elaborations based on: McKee *et al.* [1993] for *SPI*, Morid *et al.* [2006] and Dogan *et al.* [2012] for PN and Di, Hänsel *et al.* [2016], and van Rooy [1965] for *RAI*.

order to describe the evolution of drought values, we performed the Mann–Kendall (MK) trend method, which indicates the rates of variation of the drought indices.

Mann–Kendall (MK) test

The non-parametric Mann–Kendall trend (MK) is the rank-based test [Sneyers 1975] used to assess the significance of a trend in hydro-meteorological variables in time series at different levels of statistical significance [Gocic, Trajkovic 2013; Khezazna *et al.* 2017]. The statistical significance of the trends at a significance level of p = 0.05, positive values of Mann–Kendall statistics indicates increasing trends while negative values show decreasing trends at a significance level [Fniguire *et al.* 2017; Khezazna *et al.* 2017] it is not important to define if the trend is linear or not [da Silva *et al.* 2015]. This trend detection method has advantages like non-assumption of any distribution form for the data; thus extreme values are acceptable [Bari Abarghouei *et al.* 2011; Hirsch *et al.* 1982; Rahman *et al.* 2016]. The correlation between two variables is termed as the Kendall's correlation coefficient or Kendall statistics [Bari Abarghouei *et al.* 2011].

Pearson's correlation

Pearson's coefficient of correlation was described by Karl Pearson in 1896, the standard method of its calculation. He called this method the "product-moments" method (or the Galton function for the coefficient of correlation *r*). An important assumption in Pearson's 1896 contribution is the normality of the variables analysed, which could be true only for quantitative variables. Pearson's correlation coefficient is a measure of the strength of the linear relationship between two sets of data [Hauke, Kossowski 2011; Pearson 1896; 1900].

Spearman's rho correlation

Spearman's rank correlation coefficient is a nonparametric (distribution-free) rank statistic proposed as a measure of the strength of the association between two variables. Spearman's coefficient is not a measure of the linear relationship between two variables. It is a measure of a monotone association, where it assesses how well an arbitrary monotonic function can describe the relationship between two variables, without making any assumptions about the frequency distribution of the variables. Unlike Pearson's product-moment correlation coefficient, it does not require the assumption that the relationship between the variables is linear. In principle, Spearman's rho coefficient (r_s) is simply a case of Pearson's product-moment coefficient in which the data are converted to ranks before calculating the coefficient [Hauke, Kossowski 2011; Spearman 1910].

Correlation analysis is often used in hydrology for presenting the relationships between the variables, and it gives predictions of observations yet to be made. The nonparametric method is very desirable because it does not require a rigidly defined class [Kaz 1987]. Coefficient values can range from +1 to −1, where +1 indicates a perfect positive relationship, −1 indicates a perfect negative relationship, and a 0 indicates no relationship exists [Krause *et al.* 2005]. The high degree of correlation of value lies between ±0.50 and ±1,00 indicating a strong correlation. And medium correlation for values lies between ±0.30 and ±0.49, while small correlation for values lies below +29.

RESULTS AND DISCUSSION

COMPARISON OF DROUGHT CATEGORIES

At annual scale, Figure 2 shows that *PN* detected the highest range of normal droughts categories approximately (from 30 to 50%) for Beni Bahdel, Sebdou, and Khemis stations, while the rest of the stations indicated similarity of ranges between moderate droughts, normal and moderate wet categories (from 15 to 20%). Extreme droughts categories range was found (100%) on a seasonal time scale for Sebdou station. For the rest of the stations, the percentage of moderately wet categories indicated the highest range approximately (from 25 to 40%) compared to other categories. At monthly scale, extreme dry and moderate wet categories were found in similar range (35%).

On an annual scale, *RAI* detected a range of normal categories (30%) for Djbel Chouachi, several droughts approximately (from 20 to 30%) for Ouled Mimoun, Sidi Benkhala, Chouly and Khemis, and moderate droughts (20%) for the other stations. Extreme, several droughts and normal range were found approximately (from 15 to 20%) on a seasonal time scale for all stations, in addition to observation of a significant range of several droughts categories approximately (from 10 to 20%) for Djbel Chouachi, Hennaya, and Sidi Benkhala. Extreme, several droughts, and normal categories were found similarity ranges with approximation (from 15 to 20%) for all stations, expect Djebel Chouachi, which has the highest range of extreme droughts with (30%) on a monthly scale.

SPI and *DI* indices detected higher ranges of only normal categories for all stations and on all time scales, whereas *SPI* detected approximately range (from 65 to 75%). *DI* indicated approximately ranges 40%, from 40 to 45%, from 30 to 40% on annual, seasonal, and monthly time scale respectively.

As concluded: *SPI* and *DI* have responded in more consistent on all time scales for all stations. *SPI* has the most similar response to *DI* (normal categories), although *DI* underestimated the range of normal categories than *SPI* did on all time scale, where *SPI* has a much large rate of "normal categories", while the rest of the categories of drought have less rate in *SPI* compared to *DI*. This indicates high sensitivity on the part of *DI* to rainfall amount, whereas the *SPI* is the worst in detecting the extreme, severe drought (<5%).

PN and *RAI* resulted in values indicating more drought categories than *SPI* and *DI*, where they were able to detect gradual categories in droughts that cannot be detected by the *SPI* and *DI*. This analysis indicates that the application of *RAI* and *PN* allowed leading to a detailed assessment of the drought situation in the study area. Extreme droughts had also been overestimated by *PN* and *RAI* on seasonal and monthly scale but underestimated on annual scale.

METEOROLOGICAL INDICES TEMPORAL EVOLUTION

The four indices (*SPI*, *RAI*, *DI*, *PN*) at the annual time scale were compared and displayed in Figure 3, which contribute in detecting the dry and wet years in time series according to the position of the indices values in range category of drought classification that is defined in Table 2. The variance of two indices *SPI* and *RAI* is characterized by the same consistency change in wet and dry periods, it can be seen from the Figure 3

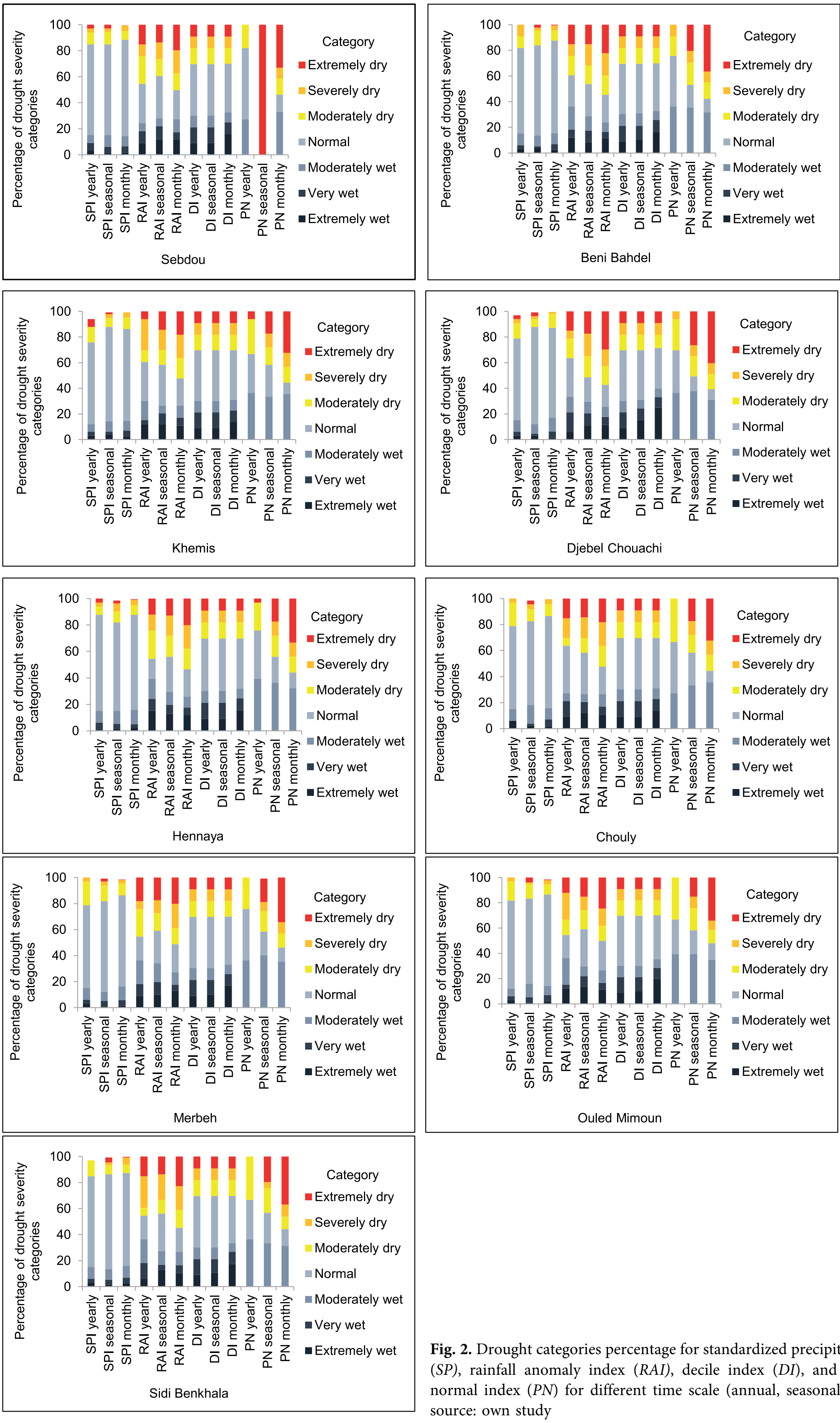

Fig. 2. Drought categories percentage for standardized precipitation index (*SP*), rainfall anomaly index (*RAI*), decile index (*DI*), and percent of normal index (*PN*) for different time scale (annual, seasonal, monthly); source: own study

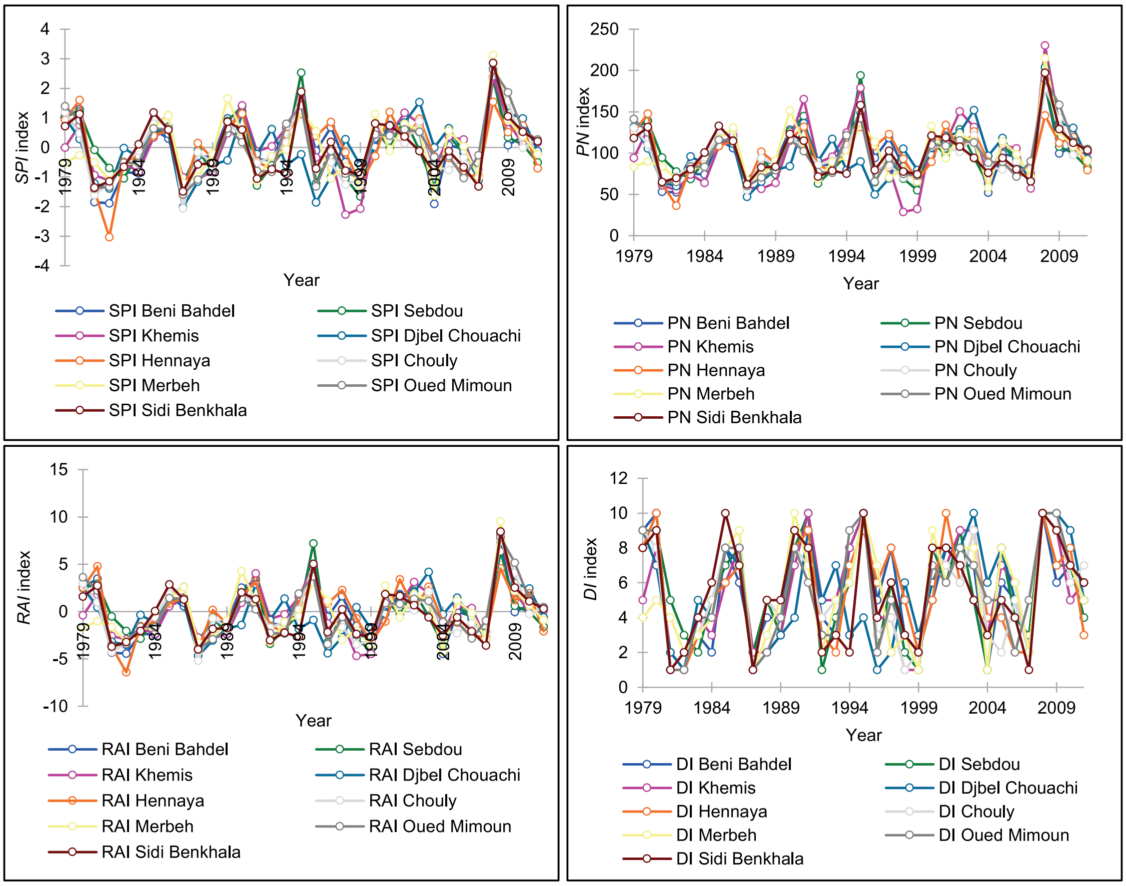

Fig. 3. All indices comparison for all rainfall stations at annual scale; *SPI*, *RAI*, *DI* and *PN* as in Tab. 2; source: own study

that the *SPI* time series of the curve is close to that of *RAI*. The period between 2000 and 2004 and 2008 and 2011 shows a recovery from drought. The highest values of the *SPI*, *RAI*, and *PN* are 3, 8, 230 respectively in 2008 correspond Sidi Benkhala station for *SPI* and *RAI* and Khemis station for *PN* which representing the "wet extremes" categories and the lowest values are –3, –6, 36 respectively in 1982 correspond Hennaya station, which representing the "dry extremes". While *DI* results showed that the highest and the lowest values (10, 1 respectively) on the annual scale are the same for some stations (Sidi Benkhala, Ouled Mimoun, Djbel Chouachi, Hennaya), which representing the "wet extremes" and "dry extremes" respectively.

The results of *SPI* and *RAI* showed that the estimates of droughts experienced a difference in terms of values, however, they are consistent in duration in terms of the start and end of the drought.

In the early 2000s, all stations showed mostly positive *SPI*, *RAI*, *PN*, and *DI* values which are often greater than 2, 4, 152, 10 respectively with the exception years 2004, 2006, and 2007. Negative values are less than –2, –4, 55, 1 respectively observed between 1981 and 1999. The year 1982 was one of the driest years, and 2008 was the wettest year in the study area.

RELATIONSHIP BETWEEN *SPI* AND *RAI*, *DI*, *PN*

In Table 3, the relationship between *SPI* and the indices *RAI*, *DI* and, *PN* were determined with the coefficient of Pearson and Spearman correlation tests on the different time scale (annual, seasonal, monthly). The results showed that the relationship for the *SPI* versus the *RAI*, *DI,* and *PN* are highly correlated (>0.6) for all time scale. The relationship has a strong positive correlation on an annual scale (≥0.94) and even higher with Spearman correlation tests (≥0.99) for all stations.

The highest Pearson correlation (0.99) was observed in several stations on annual scale, and the lowest (0.61) was observed between *SPI* and *PN* in Djbel Chouachi on a monthly scale.

The highest Spearman correlation (1.00) was observed between *SPI* and the indices *PN* and *RAI* for all stations on annual scale, and the lowest (0.59) was observed between *SPI* and *PN* in Djbel Chouachi on a monthly scale. For both correlation tests, *RAI* showed that it has the greatest correlation with *SPI* on all time scale. Overall, it is noted that the correlation of *SPI* with other indices increases with the long term in the time step and decrease with the short term.

Star diagram use to represent the relationship between variables to a central idea, and compare multiple items (correlation coefficient between indices) against multiple criteria (time steps). Figure 4 demonstrates the visualization results of Table 3, it is showed with Pearson correlation that Khemis station has the lowest correlation between *SPI* and each of the other indices at annual and seasonal scale except the correlation between *SPI* and *DI* on annual scale and between the *SPI* and *RAI* on seasonal scale, on another hand, the correlation between *SPI* and other indices was the lowest at Djbel Chouachi. While the lowest Spearman's correlation between *SPI* and each one of the indices was indicated at Khemis station at all-time scale except between the indices *SPI*, *PN* and *DI* on the monthly scale and *RAI* on the annual scale.

Table 3. The correlation coefficients between standardized precipitation index (*SPI*) and decile index (*DI*), percent of normal index (*PN*), and rainfall anomaly index (*RAI*), respectively at different time scale

Correlation test	Station	Annual			Monthly			Seasonal		
		***SPI* vs.**								
		DI	***PN***	***RAI***	***DI***	***PN***	***RAI***	***DI***	***PN***	***RAI***
Pearson	Beni Bahdel	0.97	0.99	0.99	0.87	0.81	0.91	0.95	0.83	0.96
	Sebdou	0.96	0.99	0.99	0.94	0.85	0.94	0.96	0.86	0.96
	Khemis	0.96	0.97	0.98	0.7	0.64	0.72	0.79	0.74	0.83
	DjbelChouachi	0.99	0.98	0.96	0.68	0.61	0.76	0.9	0.72	0.92
	Hennaya	0.95	0.99	0.99	0.91	0.8	0.92	0.97	0.88	0.97
	Chouly	0.96	0.99	0.99	0.9	0.76	0.92	0.95	0.91	0.97
	Merbeh	0.94	0.99	0.99	0.9	0.84	0.94	0.95	0.93	0.97
	Ouled Mimoun	0.97	0.99	0.99	0.81	0.76	0.88	0.96	0.93	0.97
	Sidi Benkhala	0.95	0.99	0.99	0.88	0.76	0.89	0.95	0.81	0.96
Sperarman's rho	Beni Bahdel	0.99	1	1	0.89	0.86	0.93	0.98	0.96	0.99
	Sebdou	0.99	1	1	0.96	0.94	0.98	0.99	0.98	0.99
	Khemis	0.99	1	1	0.7	0.66	0.71	0.8	0.78	0.81
	DjbelChouachi	0.99	1	1	0.64	0.59	0.75	0.96	0.87	0.95
	Hennaya	0.99	1	1	0.93	0.89	0.95	0.99	0.97	0.99
	Chouly	0.99	1	1	0.92	0.89	0.94	0.99	0.99	0.99
	Merbeh	0.99	1	1	0.91	0.89	0.94	0.98	0.99	0.99
	Ouled Mimoun	0.99	1	1	0.81	0.78	0.86	0.99	0.98	0.99
	Sidi Benkhala	0.99	1	1	0.91	0.84	0.91	0.99	0.95	0.99

Explanations: *SPI*, *RAI*, *DI* and *PN* as in Tab. 2.
Source: own study.

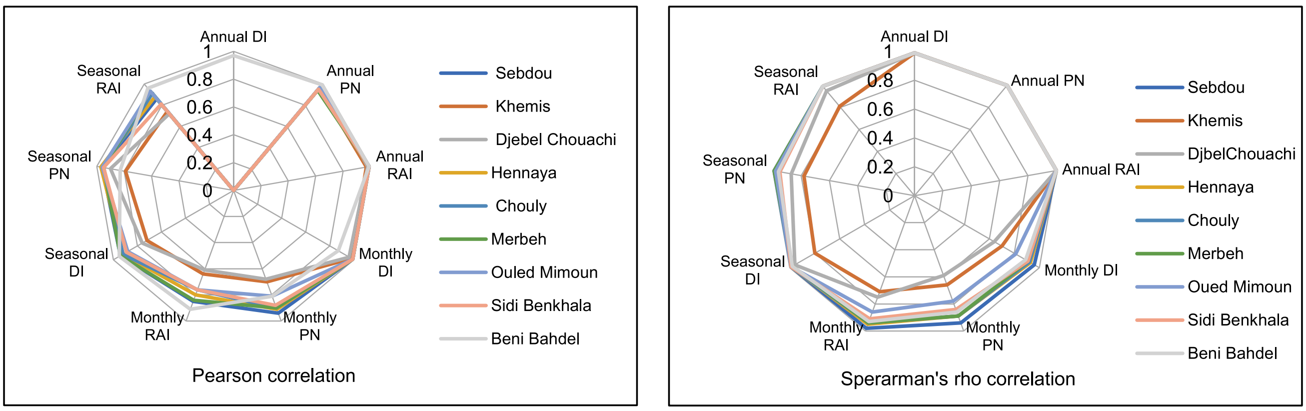

Fig. 4. The spider chart displays the time scale variations of correlation coefficient between standardized precipitation index (*SPI*) and other indices; *SPI*, *RAI*, *DI*, *PN* as in Tab. 2; source: own study

The higher correlation coefficient between 0.99 and 1 for the indices and the stations and time scales signifies that these indices are well suited and adapted in the study area. The close similarity in coefficient values in different stations can be due to the indices values, which include zero or a small number for the entire time period, that can possibly be attributed to the consistent correlation may be due to similarity of hydrological conditions of area surrounding by each station.

COMPARATIVE EVALUATION OF DROUGHT INDICES

The Figures 5, 6, and 7 represented the average of *SPI*, *RAI*, *DI*, and *PN* for annual, seasonal, and monthly time steps compared with average rainfall on each time scale.

On an annual scale, the analysis of the results indicated that extremely dry category was detected in 1982 with *RAI*, *DI* and, *PN*, where had been a significant decrease in annual average

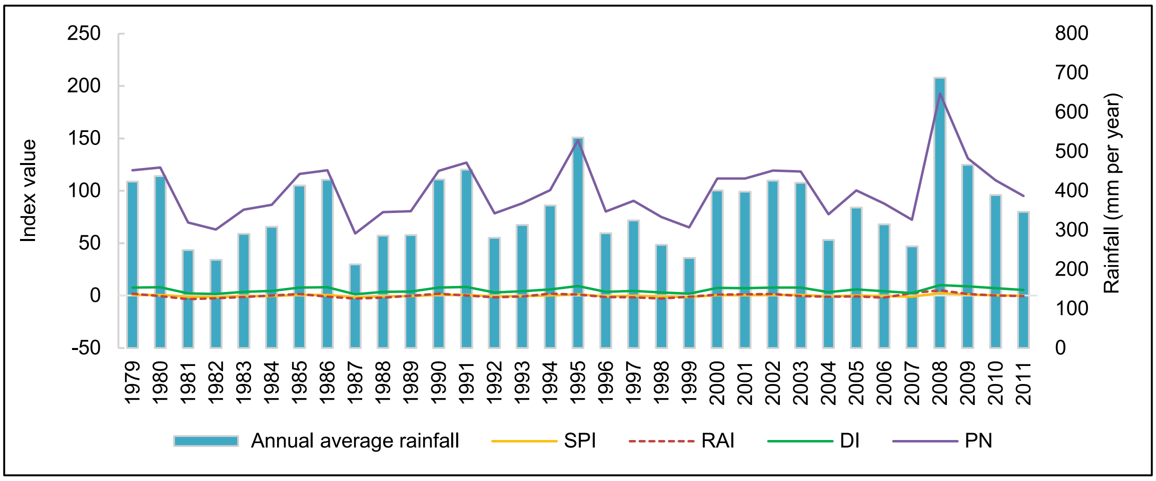

Fig. 5. Average time series of all indices and rainfall at annual scale; *SPI*, *RAI*, *DI* and *PN* as in Tab. 2; source: own study

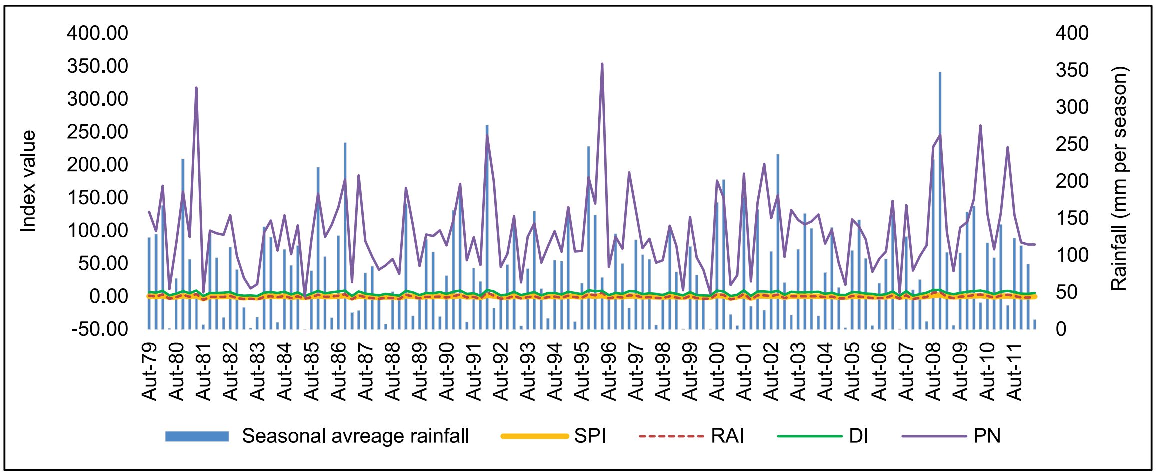

Fig. 6. Average time series of all indices and rainfall at seasonal scale; *SPI*, *RAI*, *DI* and *PN* as in Tab. 2; source: own study

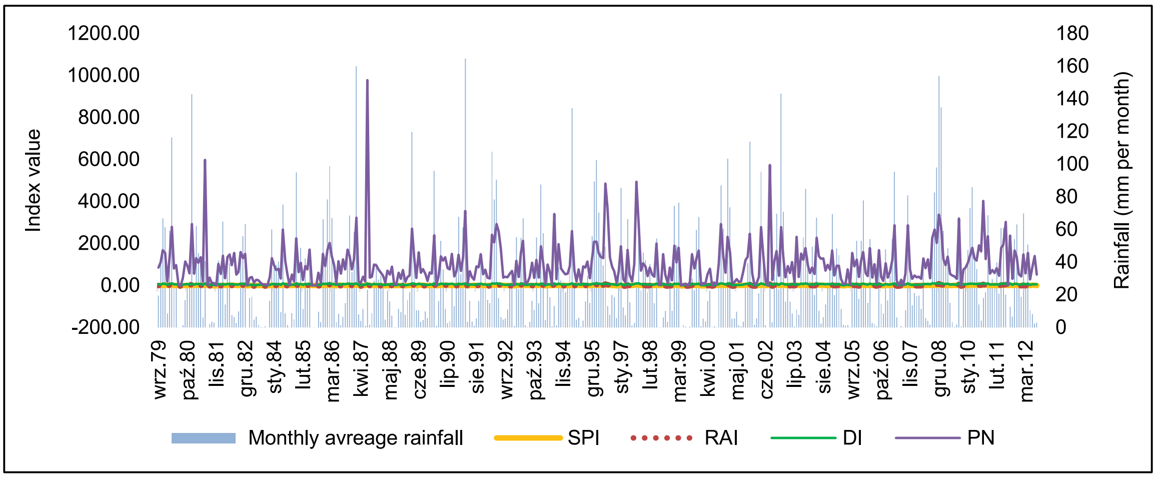

Fig. 7. Average time series of all indices and rainfall at monthly scale; *SPI*, *RAI*, *DI* and *PN* as in Tab. 2; source: own study

rainfall, in addition to 1987 and 1999 that were also shown as extremely dry with *RAI*, where the period between 1984 and 1999 experienced a fluctuation in the deficit rainfall time series. On seasonal and monthly scale, the extremely dry category were determined with *RAI* in the spring of 1982 (Fig. 6), and in April of 1983, respectively due to a decrease of rainfall in this season parallel to his months (April) which is experienced this region.

While the severely dry category was determined in 1987, 1999 with *SPI* and *DI*. This category on the seasonal scale was detected in the spring of 1982 with *DI* and *PN*, and in the spring (1987, 1999), with *SPI*, *DI*, and *PN*, where this season of these years showed mostly the deficit in seasonal rainfall. As well as this category was indicated on a monthly scale in March of 1983 and May of 1983 with *RAI*, and February of 1983 to May of 1983 with

PN, whereas April of 1983 with *DI*, and March and April of the two years of 1987 and 1999 with the *DI*, and *PN*.

The moderate dry category was indicated in 1987, 1999, and 2007 with *PN*, and the same index determined the year 1995 as the moderate wet category. Otherwise, this year was represented under the extreme wet category with *RAI*, and as very wet with *SPI* and *DI* due to the excess of rainfall in this year.

The category of extreme wet was appropriately detected in 2008 with all four indices, where the highest rainfall occurred throughout the study period. The period between 2000 and 2011 defined a slight raising of average rainfall (except 2004, and 2007). The same category was indicated on a seasonal scale in the autumn of 2008 with *RAI*, *DI*, and *PN*, it is seen and confirmed also as extremely wet in the months from September of 2008 to November of 2008. While *SPI* defined this season as severely wet as well as the month of October of 2008.

Overall, all indices indicated similar droughts categories when it was the highest and lowest of rainfall on annual time scale. It is noted that *RAI* was more appropriate compared to other indices in the detection of drought in the long term and short term. When the average rainfall was lower than normal, the *RAI* index showed an extreme dry situation, especially in 1987, 1999 and the worst dry period was reported in 1982. The deficit and fluctuation of rainfall detected the drought situation, and that showed a positive relationship between the drought indices and average rainfall.

Several studies have indicated the same results in line with our research [Adjim, Djedid 2018; Hamlaoui-Moulai *et al.* 2013; Hammar *et al.* 2014; Khezazna *et al.* 2017; Medejerab, Henia 2005], as these studies showed that the 1980s experienced a decrease in the rainfall, and considered as a dry sequence, it was observed mostly that drought index is often less than –1. While the period from 1999 to 2011 of the study was considered as a wet sequence with a drought index range from 0.06 to 0.85, and it was pointed out that 2008 as the mostly wettest in this period that was confirmed with the studies that was mentioned above.

CORRELATIONS BETWEEN DROUGHT INDICES

In order to assess the sensitivity and robustness of the indices at a different time scale, we adopt the correlation coefficient method for choosing the better relationship between the one drought index for different stations (the study stations). For this section, the correlation coefficient values are obtained by taking the average of the correlation coefficient (Pearson, Sperarman's rho) to obtain one value for each index from all the stations at different time scales(annual, seasonal, monthly)to consider which time steps of the indices may have better correlation coefficients. The obtained results of *SPI* for Pearson correlation between different stations had the best correlation on the time steps of seasonal and monthly, the average coefficients for these time steps were (0.82, 0.78 respectively). While on annual scale were around 0.78. Whereas *DI*, *PN* were significantly higher (0.8). Unlike Sperarman's rho correlation showed that *RAI* have the best correlation on both seasonal and monthly scale (0.8, 0.78 respectively), and the similar results with all indices (0.77) except *DI* (0.76) on annual scale. The results of correlation test between drought indices showed in Table 4 and Figure 8.

In conclusion, *SPI* and *RAI* were highly correlated on short-term (monthly) and medium (seasonal) is better suited for understanding and assessment of drought analysis in the study area, they were able to detect the period of drought which they found reasonable results of the drought performance reflecting

Table 4. Average correlation coefficients of indices from all stations with different time scale

Correlation test	Annual				Seasonal				Monthly			
	SPI	*RAI*	*DI*	*PN*	*SPI*	*RAI*	*DI*	*PN*	*SPI*	*RAI*	*DI*	*PN*
Pearson	0.78	0.8	0.76	0.8	0.82	0.78	0.79	0.7	0.78	0.74	0.73	0.66
Sperarman's rho	0.77	0.77	0.76	0.77	0.79	0.8	0.79	0.79	0.77	0.78	0.73	0.76

Explanations: *SPI*, *RAI*, *DI* and *PN* as in Tab. 2.
Source: own elaboration

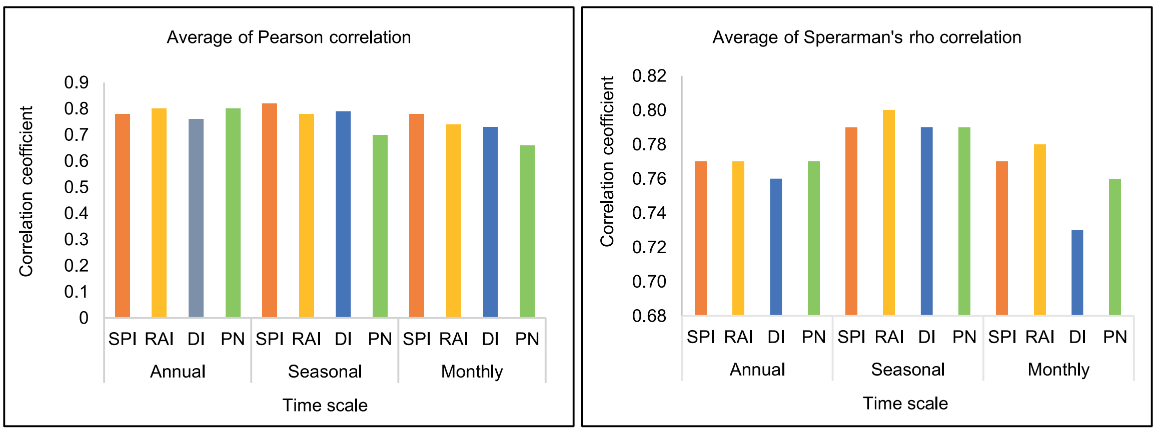

Fig. 8. Average correlations of all indices with a different time scale from all stations; *SPI*, *RAI*, *DI* and *PN* as in Tab. 2; source: own study

the real situation of climate for this area without underestimated or overestimated the drought categories and their period.

Almost all indices reached a high correlation between the stations (0.82) may due to the fact that drought is strongly affected by rainfall, the low variation of rainfall amount led to this similarity of the strong correlation where the geographical coverage (distance) between the stations was small.

TREND ANALYSIS

The results of trend analysis Mann–Kendall (MK) test on different time series of drought indices for a period of 1979–2011 are presented in Table 5. Overall, all the indices exhibited no considerably significant trend at the various stations on Annual and Seasonal scale except Djbel Chouachi station that were recorded significant positive trend (0.13 at p = 0.05 level of statistical significance) on seasonal scale for *RAI*, and *DI*. Whereas, for monthly scale, the trend provided by indices were significantly positive in Djbel Chouachi and Merbeh station, and the same result for Sidi Benkhala station except *RAI* index that showed no significant trend, while the stations Khemis, Chouly, and Ouled Mimoun detected positive trend with one of this indices *SPI*, *DI*, and *RAI* respectively. For the rest of stations showed positive but not significant trend, and indicated almost similar positive values for all stations on Monthly scale, that display wet event means that the positive of the indices are considerable in the sequence of the indices values.

The positive trend of meteorological indices in monthly scale may demonstrated by the positive trend of rainfall in this region [Bendjema *et al.* 2019; Bougara *et al.* 2020; Donat *et al.* 2014; Dünkeloh, Jacobeit 2003; Philandras *et al.* 2011; Tramblay *et al.* 2012]. The study area experienced a significance raising of rainfall during the period 2000–2011 which was due the North Atlantic Oscillation (NAO) index describing the NAO phenomenon. This phenomenon is a pressure difference between Azores and Iceland, and its negative correlation with rainfall [Lopez, Frances 2010], and that affect West Africa in the Mediterranean region [Nouaceur *et al.* 2017]. The negative phase of NAO index have impacts on increasing of rainfall in north Africa [Brandimarte *et al.* 2011; Hamlaoui-Moulai *et al.* 2013; Meddi *et al.* 2010], the probability for wet months (October–March) is around 42%–52% for a negative NAO [Muñoz-Díaz, Rodrigo 2003; Philandras *et al.* 2011]. While from the middle of 1970 to 2000, the NAO represented a positive phase caused a decreasing trend of rainfall [Hamlaoui-Moulai *et al.* 2013], it has been confirmed with our study results, where the meteorological indices indicated a drought situation between 1980 and 1999, and it was strong in 1982 for the study period. Where the study of Achour *et al.* [2020] pointed out that seven plains of north-western Algeria are affected by the drought based on *SPI* at different time scales using artificial neural network (ANN) model, and it changes according to the time scale, depicts identified dry trend in terms of severity and duration rising from east to west especially after 1981, and they suggested ANN-based drought forecast model can be conveniently adopted to establish with two months ahead adequate irrigation schedules in case of water stress and for optimizing agricultural production, while the study of Habibi *et al.* [2018] using same index with applying Markov chains to identify consecutive drought years of two years, it has shown alternating wet and dry sequences with more dominant long periods of wet years (1984–1992), and the period 2006–2010 was again wetter than normal as was confirmed with current research.

CONCLUSIONS

The main purpose of this study was a comparative assessment of drought for the Tafna basin and allowed discussion on the performance of the indices during the period 1979–2011 for nine rainfall stations. The analysis of meteorological indices have shown that the standardized precipitation index (*SPI*) and decile index (*DI*) have performed similar responses to the drought categories. Where the similarity of data level (rainfall input), and the simplicity of calculations of these indices led to removing the difference between the indices. Where rainfall anomaly index (*RAI*) and percent of normal index (*PN*) were found to be more able to detect more drought categories and describe the drought conditions well compared with the *SPI* and *DI*. All indices

Table 5. Mann–Kendall test results of all indices at all stations in different time sale

Station	Annual				Seasonal				Monthly			
	SPI	*DI*	*PN*	*RAI*	*SPI*	*DI*	*PN*	*RAI*	*SPI*	*DI*	*PN*	*RAI*
Beni Bahdel	0.05	0.06	0.05	0.05	0.06	0.07	0.06	0.07	0.05	0.06	0.06	0.06
Sebdou	–0.03	–0.01	–0.03	–0.03	0.01	0.02	0.01	0.01	0.04	0.03	0.04	0.04
Khemis	0.17	0.18	0.17	0.17	0.11	0.02	0.01	0.01	**0.08***	0.03	0.04	0.04
Djbel Chouachi	0.22	0.23	0.22	0.22	0.12	**0.13***	0.11	**0.13***	**0.09***	**0.10***	**0.09***	**0.09***
Hennaya	0.03	0.07	0.03	0.03	0.05	0.06	0.03	0.04	0.04	0.04	0.04	0.04
Chouly	0.05	0.07	0.05	0.05	0.05	0.05	0.05	0.06	0.06	**0.08***	0.05	0.06
Merbeh	0.16	0.17	0.16	0.16	0.09	0.11	0.08	0.10	**0.09***	**0.10***	**0.10***	**0.09***
Ouled Mimoun	0.13	0.14	0.13	0.13	0.07	0.07	0.07	0.07	0.06	0.06	0.07	**0.07***
Sidi Benkhala	0.07	0.05	0.07	0.07	0.06	0.05	0.06	0.05	**0.07***	**0.08***	**0.07***	0.07

* if trend at ≤0.05 level of significance.
Source: own study.

indicated similar categories of droughts when it was the highest and lowest of rainfall, where may help providing a figure of average rainfall involve the average indices for each scale better identification and characteristics analyse for drought.

The best correlation for the four indices at different time scales reflected the similarity between the durations of drought and well adapted to the study area. *SPI* is recommended for use in comparison studies since it has good correlations with various time steps of other indices.

Tafna basin was characterized by normal drought on study time period. However the meteorological indices determined extreme drought during 1982. While the extremely wettest was in 2008 during the wet period 2000–2011.

The drought indices considered in this study are based on only rainfall and might tend to underestimate the real drought risk. Thus it should be evaluated using indices that include temperature and evapotranspiration, where the rising of the temperatures potentially increases evapotranspiration rates and may aggravate drought conditions.

The results of trends based on the Mann–Kendall test showed generally no tendency of the indices series on the annual and seasonal scale except Djbel Chouachi station that has an upward trend with *RAI*, *DI* on a seasonal scale. On the other hand, the significantly positive trend in the indices was mostly detected on the monthly scale.

The assessment of the influence of North Atlantic Oscillation (NAO) on drought revealed that the dry and wet events during the period of the study are associated with the positive or negative phase of NAO, where the positive phase of NAO matched with the dry period 1980–1999, and the negative phase with the wet period 2000–2011. According to the drought trends and the percentile of categories, the water resource management strategies should be adjusted, especially in the rainfall seasons (September–May months), where the deficit of water resources may affect agricultural activities in semi-arid regions. It is noted that the drought trend basically related to rainfall trends. Focusing on these trends is inevitable during the decision-making of strategies for water resources related to agricultural production.

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REFERENCES

Abdelmalek M.B., Nouiri I. 2020. Study of trends and mapping of drought events in Tunisia and their impacts on agricultural production. Science of The Total Environment. Vol. 734, 139311. DOI 10.1016/j.scitotenv.2020.139311.

Achour K., Meddi M., Zeroual A., Bouabdelli S., Maccioni P., Moramarco T. 2020. Spatio-temporal analysis and forecasting of drought in the plains of northwestern Algeria using the standardized precipitation index. Journal of Earth System Science. Vol. 129(42) p. 1–22. DOI 10.1007/s12040-019-1306-3.

Adjim H., Djedid A. 2018. Drought and water mobilization in semi-arid zone: The example of Hammam Boughrara dam (North-West of Algeria). Journal of Water and Land Development. No. 37 p. 3–10. DOI 10.2478/jwld-2018-0019.

Afzali A., Keshtkar H., Pakzad S., Moazami N., Farahani E.A., Khosrojerdi E., Yousefi Z., Taghinaghilou M. 2016. Spatio-temporal analysis of drought severity using drought indices and deterministic and geostatistical methods (Case study: Zayandeh-roud River Basin). Desert. Vol. 21. No. 2 p. 165–172. DOI 10.22059/jdesert.2016.60325.

Akbari H., Rakhshandehroo G.R., Sharifloo A.H., Ostadzadeh E. 2015. Drought analysis based on standardized precipitation index (SPI) and streamflow drought index (SDI) in Chenar Rahdar River Basin, Southern Iran. Proceedings of the Watershed Management Symposium. 5–7.08.2015 Reston, VA p. 11–22. DOI 10.1061/9780784479322.002.

Al-Timimi Y.K., Osamah A. 2016. Comparative study of four meteorological drought indices in Iraq. IOSR Journal of Applied Physics. Vol. 8. Iss. 5 p. 76–84. DOI 10.9790/4861-0805037684.

Asefjah B., Fanian F., Feizi Z., Abolhasani A., Paktinat H., Naghilou M., Atani A.M., Asadollahi M., Babakhani M., Kouroshniya A., Salehi F. 2014. Meteorological drought monitoring using several drought indices (Case study: Salt Lake Basin in Iran). Desert. Vol. 19. No. 2 p. 155–165. DOI 10.22059/jdesert.2014.52344.

Azarakhshi M., Mahdavi M., Arzani H., Ahmadi H. 2011. Assessment of the Palmer drought severity index in arid and semi-arid rangeland: (Case study: Qom province, Iran). Desert. Vol. 16 p. 77–85. DOI 10.22059/jdesert.2012.24739.

Bagheri F. 2016. Mapping drought hazard using SPI index and GIS (A case study: Fars Province, Iran). International Journal of Environment and Geoinformatics. Vol. 3. No. 1 p. 22–28. DOI 10.30897/ijegeo.304419.

Bari Abarghouei H., Zarch M. A. A., Dastorani M. T., Kousari M. R., Zarch M.S. 2011. The survey of climatic drought trend in Iran. Stochastic Environmental Research and Risk Assessment. Vol. 25. No. 6 p. 851–63. DOI 10.1007/s00477-011-0491-7.

Barua S., Ng A.W.M., Perera B.J.C. 2011. Comparative evaluation of drought indexes: Case study on the Yarra River catchment in Australia. Journal of Water Resources Planning and Management. Vol. 137. No. 2 p. 215–226. DOI 10.1061/(ASCE)WR.1943-5452.0000105.

Bayissa Y.A., Moges S.A., Xuan Y., van Andel S.J., Maskey S., Solomatine D.P., Griensven A., van Tadesse T. 2015. Spatio-temporal assessment of meteorological drought under the influence of varying record length: The case of Upper Blue Nile Basin, Ethiopia. Hydrological Sciences Journal. Vol. 60 p. 1927–1942. DOI 10.1080/02626667.2015.1032291.

Bazrafshan J., Khalili A. 2013. Spatial analysis of meteorological drought in Iran from 1965 to 2003. Desert. Vol. 18 p. 63–71. DOI 10.22059/jdesert.2013.36276.

Bendjema L., Baba-Hamed K., Bouanani A. 2019. Characterization of the climatic drought indices application to the Mellah catchment, North-East of Algeria. Journal of Water and Land Development. No. 43 (X–XII) p. 28–40. DOI 10.2478/jwld-2019-0060.

Beran M.A., Rodier J.A. 1985. Hydrological aspects of drought. Ser. Studies and Reports in Hydrology. No. 39. Paris. UNESCO–WMO. ISBN 92-3-102288-1 pp. 149.

Bouabdelli S., Meddi M., Zeroual A., Alkama R. 2020. Hydrological drought risk recurrence under climate change in the karst area of Northwestern Algeria. Journal of Water and Climate Change. Vol. 11(S1) p. 164–188. DOI 10.2166/wcc.2020.207.

Bouanani A. 2004. Etude de quelques sous bassins de la Tafna (NW-Algérie) [Study of some Tafna sub-basins (NW-Algeria)]. PhD Thesis. Tlemcen, Algeria. University of Abou Bekr Belkaid pp. 250.

Boudad B., Sahbi H., Mansouri I. 2018. Analysis of meteorological and hydrological drought based in SPI and SDI index in the Inaouen Basin (Northern Morocco). Journal of Materials and Environmental Sciences. Vol. 9. No. 1 p. 219–227. DOI 10.26872/jmes.2018.9.1.25.

Bougara H., Baba Hamed K., Borgemeister C., Tischbein B., Kumar N. 2020. Analyzing trend and variability of rainfall in the Tafna Basin (Northwestern Algeria). Atmosphere. Vol. 11. Iss. 4, 347. DOI 10.3390/atmos11040347.

Brandimarte L., di Baldassarre G., Bruni G., D'Odorico P., Montanari A. 2011. Relation between the North-Atlantic Oscillation and hydroclimatic conditions in Mediterranean areas. Water Resources Management. Vol. 25. No. 5 p. 1269–1279. DOI 10.1007/s11269-010-9742-5.

Da Silva R.M., Santos C.A.G., Moreira M., Corte-Real J., Silva V.C.L., Medeiros I.C. 2015. Rainfall and river flow trends using Mann–Kendall and Sen's slope estimator statistical tests in the Cobres River basin. Natural Hazards. Vol. 77. No. 2 p. 1205–1221. DOI 10.1007/s11069-015-1644-7.

Deo R.C. 2011. On meteorological droughts in tropical Pacific islands: Time-series analysis of observed rainfall using Fiji as a case study. Meteorological Applications. Vol. 18. No. 2 p. 171–180. DOI 10.1002/met.216.

Dikici M. 2020. Drought analysis with different indices for the Asi Basin (Turkey). Scientific Reports. 10.20739. DOI 10.1038/s41598-020-77827-z.

Djellouli F., Bouanani A., Baba-Hamed K. 2016. Efficiency of some meteorological drought indexes in different time scales, case study: Wadi Louza basin NW-Algeria. Journal of Water and Land Development. No. 31 p. 33–41. DOI 10.1515/jwld-2016-0034.

Djellouli F., Bouanani A., Baba-Hamed K. 2018. Climate change: Assessment and monitoring of meteorological and hydrological drought of Wadi El Hammam basin (NW-Algeria). Journal of Fundamental and Applied Sciences. Vol. 8. No. 3 p. 1037. DOI 10.4314/jfas.v8i3.20.

Dogan S., Berktay A., Singh V.P. 2012. Comparison of multi-monthly rainfall-based drought severity indices, with application to semi-arid Konya closed basin, Turkey. Journal of Hydrology. Vol. 470 p. 255–268. DOI 10.1016/j.jhydrol.2012.09.003.

Donat M.G., Peterson T.C., Brunet M., King A.D., Almazroui M., Kolli R.K., Boucherf D., Al-Mulla A.Y., Nour A.Y., Aly A.A. 2014. Changes in extreme temperature and precipitation in the Arab Region: Long-term trends and variability related to ENSO and NAO: Extreme temperature and precipitation in the Arab Region. International Journal of Climatology. Vol. 34 p. 581–592. DOI 10.1002/joc.3707.

Dünkeloh A., Jacobeit J. 2003. Circulation dynamics of Mediterranean precipitation variability 1948–98: Circulation dynamics of Mediterranean precipitation variability. International Journal of Climatology. Vol. 23. No. 15 p. 1843–1866. DOI 10.1002/joc.973.

Edwards D.C., McKee T.B. 1997. Characteristics of 20th century drought in the United States at multiple times scales. Atmospheric Science Paper. Vol. 634 p. 1–30.

Farahmand A., AghakouchakA. 2019. A generalized framework for deriving nonparametric standardized drought indicators. Advances in Water Resources. Vol. 76 p. 140–145. DOI 10.1016/j.advwatres.2014.11.012.

Fniguire F., Laftouhi N.E., Saidi M.E., Zamrane Z., El Himer H., Khalil N. 2017. Spatial and temporal analysis of the drought vulnerability and risks over eight decades in a semi-arid region (Tensift Basin: Morocco). Theoretical and Applied Climatology. Vol. 130. No. 1–2 p. 321–330. DOI 10.1007/s00704-016-1873-z.

Gader K., Gara A., Vanclooster M., Khlifi S., Slimani M. 2020. Drought assessment in a South Mediterranean Transboundary Catchment. Hydrological Sciences Journal. Vol. 65. Iss. 8 p. 1300–1315. DOI 10.1080/02626667.2020.1747621.

Gedefaw M., Yan D., Wang H., Qin T., Girma A., Abiyu A., Batsuren D. 2018. Innovative trend analysis of annual and seasonal rainfall variability in Amhara Regional State, Ethiopia. Atmosphere. Vol. 9, 326 p. 1–10. DOI 10.3390/atmos9090326.

Ghenim A.N., Megnounif A., Seddini A., TerfousA. 2010. Fluctuations hydro-pluviométriques du bassin-versant de l'ouedTafna à Béni Bahdel (Nord-Ouest algérien) [Hydro-pluviometric fluctuations of the Tafna wadi watershed in Béni Bahdel (Northwest Algeria)]. Sécheresse. Vol. 21 p. 115–120. DOI 10.1684/sec.2010.0240.

Gibbs W.J., Maher J.V. 1967. Rainfall deciles as drought indicators. Bureau of Meteorology Bulletin. No. 48. Commonwealth of Australia, Melbourne, VIC, Australia.

Gocic M., Trajkovic S. 2013. Analysis of changes in meteorological variables using Mann–Kendall and Sen's slope estimator statistical tests in Serbia. Global and Planetary Change. Vol. 100 p. 172–182. DOI 10.1016/j.gloplacha.2012.10.014.

Guttman N.B. 1998. Comparing the Palmer drought index and the standardized precipitation index. Journal of the American Water Resources Association. Vol. 34 p. 113–122. DOI 10.1111/j.1752-1688.1998.tb05964.x

Habibi B., Meddi M., Torfs P.J.J.F., Remaoun M., van Lanen H.A.J. 2018. Characterisation and prediction of meteorological drought using stochastic models in the semi-arid Chéliff–Zahrez Basin (Algeria). Journal of Hydrology: Regional Studies. Vol. 16 p. 15–31. DOI 10.1016/j.ejrh.2018.02.00510.1016/j.ejrh.2018.02.005.

Halwatura D., McIntyre N., Lechner A.M., Arnold S. 2017. Capability of meteorological drought indices for detecting soil moisture droughts. Journal of Hydrology: Regional Studies. Vol. 12 p. 396–412. DOI 10.1016/j.ejrh.2017.06.001.

Hamlaoui-Moulai L., Mesbah M., Souag-Gamane D., Medjerab A. 2013. Detecting hydro-climatic change using spatiotemporal analysis of rainfall time series in Western Algeria. Natural Hazards. Vol. 65 p. 1293–1311. DOI 10.1007/s11069-012-0411-2.

Hammar Y., Djebbar Y., Khoualdia W. 2014. Caractérisation de la variabilité climatique : Cas du bassin versant de La Medjerda (Nord-Est Algérien) [Characterization of climate variability: Case of watershed Medjerda (North East of Algeria)]. Synthèse : Revue des Sciences et de la Technologie. No. 29 p. 6–23. DOI 10.12816/0027871.

Hänsel S., Schucknecht A., Matschullat J. 2016. The Modified Rainfall Anomaly Index (MRAI) – Is this an alternative to the Standardised Precipitation Index (SPI) in evaluating future extreme precipitation characteristics. Theoretical and Applied Climatology. Vol. 123. No. 3–4 p. 827–844. DOI 10.1007/s00704-015-1389-y.

Hauke J., Kossowski T. 2011. Comparison of values of Pearson's and Spearman's correlation coefficients on the same sets of data. Quaestiones Geographicae. Vol. 30. No. 2 p. 87–93. DOI 10.2478/v10117-011-0021-1.

Hayes M.J., Svoboda M., Wilhite D.A., Vanyarkho O. 1999. Monitoring the 1996 drought using the SPI. Bulletin of the

American Meteorological Society. Vol. 80 p. 429–438. DOI 10.1175/15200477(1999)080<0429:MTDUTS>2.0.CO;2.

Hirsch R.M., Slack J.R., Smith R.A. 1982. Techniques of trend analysis for monthly water quality data. Water Resource Research. Vol. 18 p. 107–121. DOI 10.1029/WR018i001p00107.

IPCC 2014. Climate Change 2014. Synthesis report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri, L.A. Meyer (eds.)]. Geneva, Switzerland. Intergovernmental Panel. ISBN 978-92-9169-143-2 pp. 151.

Jain S.K., Vijay K. 2012. Trend analysis of rainfall and temperature data for India. Current Science. Vol. 102. No. 1 p. 37–49.

Jain V.K., Pandey R. P., Jain M.K., Byun H.R. 2015. Comparison of drought indices for appraisal of drought characteristics in the Ken River Basin. Weather and Climate Extremes. Vol. 8 p. 1–11. DOI 10.1016/j.wace.2015.05.002.

Kanellou E., Domenikiotis C., Blanta A., Hondronikou E., Dalezios N. R. 2008. Index-based drought assessment in semi-arid areas of Greece based on conventional data. European Water. Vol. 23/24 p. 87–98.

Kaz A.1987. Nonparametric techniques for analysis of hydrological events nonparametric techniques for analysis of hydrological events. Water for the Future: Hydrology in Perspective (Proceedings of the Rome Symposium, April 1987). IAHS Publ. No. 164 p. 67–76.

Ketrouci K., Meddi M., Abdesselam B. 2012. Study of the extreme floods in Algeria: The case of the Tafna catchment area. Sécheresse. Vol. 23 p. 297–305. DOI 10.1684/sec.2012.0353.

Keyantash J., Dracup J.A. 2002. The quantification of drought: An evaluation of drought indices. Bulletin of the American Meteorological Society. Vol. 83. Iss. 8 p. 1167–1180. DOI 10.1175/1520-0477-83.8.1167.

Khezazna A., Amarchi H., Derdous O., Bousakhria F. 2017. Drought monitoring in Seybouse Basin (Algeria) over the last decades. Journal of Water and Land Development. No. 33 p. 79–88. DOI 10.1515/jwld-2017-0022.

Khoualdia W., Djebbar Y., Hammar Y. 2014. Caractérisation de la variabilitéclimatique: cas du bassin versant de La Medjerda (Nord-Est algérien) [Climatic variability characterisation: Case of Medjerda watershed (northeastern Algeria)]. Synthèse: Revue des Sciences et de la Technologie. Vol. 29. No. 1 p. 6–23.

Kisi O., Ay M. 2014. Comparison of Mann–Kendall and innovative trend method for water quality parameters of the Kizilirmak River, Turkey. Journal of Hydrology. Vol. 513 p. 362–375. DOI 10.1016/j.jhydrol.2014.03.005.

Krause P., Boyle D.P., Base F. 2005. Comparison of different efficiency criteria for hydrological model assessment. Advances in Geoscience. Vol. 5 p. 89–97. DOI 10.5194/adgeo-5-89-2005.

Kumar N., Tischbein B., Beg M.K. 2019. Multiple trend analysis of rainfall and temperature for a monsoon-dominated catchment in India. Meteorology and Atmospheric Physics. Vol. 131 p. 1019–1033. DOI 10.1007/s00703-018-0617-2.

Kumar V. 1998. An early warning system for agricultural drought in an arid region using limited data. Journal Arid Environments. Vol. 40 p. 199–209. DOI 10.1006/jare.1998.0437.

Lazri M., Ameur S., Brucker J.M., Lahdir M., Sehad M. 2015. Analysis of drought areas in Northern Algeria using Markov chains. Earth System and Science. Vol. 124 pp. 61. DOI 10.1007/s12040-014-0500-6.

Lloyd-Hughes B., Saunders M. 2002. A drought climatology for Europe. International Journal of Climatology. Vol. 22. Iss. 13 p. 1571–1592. DOI 10.1002/joc.846.

Lorenzo-Lacruz J., Morán-Tejeda E. 2016. Spatio-temporal patterns of meteorological droughts in the Balearic Islands (Spain). Cuadernos de Investigación Geográfica. Vol. 42. No. 1 p. 49. DOI 10.18172/cig.2948.

Ma M., Ren L., Singh V.P., Yuan F., Chen L., Yang X., Liu Y. 2015. Hydrologic model-based Palmer indices for drought characterization in the Yellow River basin, China. Stochastic Environmental Research and Risk Assessment. Vol. 30 p. 1401–1420. DOI 10.1007/s00477-015-1136-z.

Marengo J.A., Tomasella J., Alves L.M., Soares W.R., Rodriguez D.A. 2011. The drought of 2010 in the context of historical droughts in the Amazon region. Geophysical Research Letters. Vol. 38. Iss. 12, L12703. DOI 10.1029/2011GL047436.

McCarthy J.J. 2001. Climate change 2001: Impacts, adaptation, and vulnerability: Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. ISBN 0 521 01500 6 pp. 1042.

McKee T.B., Doesken N.J., Kleist J. 1993. The relationship of drought frequency and duration to time scales. Eighth Conference on Applied Climatology. Anaheim, California. No. 1 p. 179–184.

Meddi H., Meddi M. 2009. Variabilité des précipitations annuelles du Nord-Ouest de l'Algérie [Variability of annual precipitation in North-West Algeria]. Sécheresse. Vol. 20. No. 1 p. 57–65. DOI 10.1684/sec.2009.0169.

Meddi M., Hubert P. 2003. Impact de la modification du régime pluviométrique sur les ressources en eau du Nord-Ouest de l'Algérie [Impact of the modification of the rainfall regime on the water resources of North-West Algeria]. Hydrology of the Mediterranean and Semiarid Regions. Proceedings of an international symposium held at Montpelier. IAHS Publ. No. 278 p. 229–235.

Meddi M., Toumi S., Mehaiguene M. 2013. Hydrological drought in Tafna Basin – Algeria. Proceedings of the 13th International Conference of Environmental Science and Technology, 5–7 September 2013. Athens. Greece. Academia p. 9.

Meddi M.M., Assani A.A., Meddi H. 2010. Temporal variability of annual rainfall in the Macta and Tafna catchments, Northwestern Algeria. Water Resource Management. Vol. 24 p. 3817–3833. DOI 10.1007/s11269-010-9635-7.

Medjerab A., Henia L. 2005. Régionalisation des pluies annuelles dans l'Algérie Nord-occidentale [Regionalization of annual rainfall in North-western Algeria]. Revue Géographique de l'Est. Vol. 45. No. 2. DOI 10.4000/rge.501.

Morid S., Smakhtin V., Moghaddasi M. 2006. Comparison of seven meteorological indices for drought monitoring in Iran. International Journal of Climatology. Vol. 26. Iss. 8 p. 971–985. DOI 10.1002/joc.1264.

Mrad D., Dairi S., Boukhari S., Djebbar Y. 2018b. Caractérisation de la secheresse: Cas du bassin Versant Seybouse [Characterization of the drought: Case of the Seybouse watershed]. Journal International Sciences et Technique de l'Eau et de l'Environnement. Vol. III. No. 1 p. 195–198.

Mrad D., Djebbar Y., Hammar Y. 2018a. Analysis of trend rainfall: Case of North-Eastern Algeria. Journal of Water and Land Development. No. 36 p. 105–115. DOI 10.2478/jwld-2018-0011.

Muñoz-Díaz D., Rodrigo F.S. 2003. Effects of the North Atlantic Oscillation on the probability for climatic categories of local monthly rainfall in Southern Spain: NAO and rainfall Southern Spain. International Journal of Climatology. Vol. 23. No. 4 p. 381–397. DOI 10.1002/joc.886.

Nouaceur Z., Murărescu O., Murătoreanu G. 2017. Rainfall variability and trend analysis of multiannual rainfall in Romanian Plain. Annals of Valahia University of Targoviste Geographical Series. Vol. 17 p. 124–144. DOI 10.1515/avutgs-2017-0012.

Passioura J. 2007. The drought environment: physical, biological and agricultural perspectives. Journal of Experimental Botany. Vol. 58 p. 113–117. DOI 10.1093/jxb/erl212.

Pathak A.A., Channaveerappa, Dodamani B.M. 2016. Comparison of two hydrological drought indices. Perspectives in Science. Vol. 8 p. 626–628. DOI 10.1016/j.pisc.2016.06.039.

Paulo A.A., Pereira L.S. 2006. Drought concepts and characterization. Water International. Vol. 31 p. 37–49. DOI 10.1080/02508060608691913.

Pearson K. 1896. Mathematical contributions to the theory of evolution. III. Regression, heredity, and panmixia. Philosophical Transactions of the Royal Society Series. Vol. 187 p. 253–318. DOI 10.1098/rsta.1896.0007.

Pearson K. 1900. Mathematical contributions to the theory of evolution. VII. On the correlation of characters not quantitatively measurable. Philosophical Transactions of the Royal Society Series. Vol. 195 p. 1–47. DOI 10.1098/rsta.1900.0022.

Philandras C.M., Nastos P.T., Kapsomenakis J., Douvis K.C., Tselioudis G., Zerefos C.S. 2011. Long term precipitation trends and variability within the Mediterranean Region. Natural Hazards and Earth System Sciences. Vol. 11 p. 3235–3250. DOI 10.5194/nhess-11-3235-2011.

Rahman A.S., Kamruzzama M., Jahan C.S., Mazumder Q.H. 2016. Long-term trend analysis of water table using 'MAKESENS' model and sustainability of groundwater resources in drought prone Barind Area, NW Bangladesh. Journal of the Geological Society of India. Vol. 87. No. 2 p. 179–193. DOI 10.1007/s12594-016-0386-9.

Sahnoune F., Belhamel M., Zelmat M., Kerbachi R. 2013. Climate change in Algeria: Vulnerability and strategy of mitigation and adaptation. Energy Procedia. Vol. 36 p. 1286–1294. DOI 10.1016/j.egypro.2013.07.145.

Shah R.B., Nitin Manekar V. 2015. Drought index computation using Standardized Precipitation Index (SPI) method for Surat District, Gujarat. Aquatic Procedia. Vol. 4 p. 1243–1249. DOI 10.1016/j.aqpro.2015.02.162.

Shahabfar A., Eitzinger J. 2013. Spatio-temporal analysis of droughts in semi-arid regions by using meteorological drought indices. Atmosphere. Vol. 4. Iss. 2 p. 94–112. DOI 10.3390/atmos4020094.

Sneyers R. 1975. Sur l'analysestatistique des séries d'observations [On the statistical analysis of series of observations]. Note Technique. No. 143. Genève, Switzerland Secrétariat de l'Organisations Météorologique Mondiale. ISBN 9263204152 pp. 192.

Soleimani Sardou F., Bahremand A. 2014. Hydrological drought analysis using SDI index in Halilrud Basin of Iran. Environmental Resources Research. Vol. 2. No. 1 p. 47–56. DOI 10.22069/IJERR.2014.1678.

Soo Jun K., Chung E.-S., Sung J.-Y., Lee K.-S. 2011. Development of spatial water resources vulnerability index considering climate change impacts. Science of the Total Environment. Vol. 409. Iss. 24 p. 5228–5242. DOI 10.1016/j.scitotenv.2011.08.027.

Spearman C.E. 1910. Correlation calculated from faulty data. British Journal of Psychology. Vol. 3 p. 271–295. DOI 10.1111/j.2044-8295.1910.tb00206.x.

Swetalina N., Thomas T. 2016. Evaluation of hydrological drought characteristics for Bearma Basin in Bundelkh and Region of Central India. Procedia Technology. Vol. 24 p. 85–92. DOI 10.1016/j.protcy.2016.05.013.

Tabari H., Abghari H., Hosseinzadeh Talaee P. 2012. Temporal trends and spatial characteristics of drought and rainfall in arid and semi-arid regions of Iran. Hydrological Processes. Vol. 26 p. 3351–3361. DOI 10.1002/hyp.8460.

Taleb A., Belaidia N., Gagneur J. 2004. Water quality before and after dam building on a heavily polluted river in semi-arid Algeria. River Research and Applications. Vol. 20. Iss. 8 p. 943–956. DOI 10.1002/rra.800.

Tigkas D., Tsakiris G. 2014. Early estimation of drought impacts on rainfed wheat yield in Mediterranean climate. Environmental Processes. Vol. 2. Iss. 1 p. 97–114. DOI 10.1007/s40710-014-0052-4.

Tigkas D., Vangelis H., Tsakiris G. 2015. Drin C: a software for drought analysis based on drought indices. Earth Science Informatics. Vol. 8. Iss. 3 p. 697–709. DOI 10.1007/s12145-014-0178-y.

Tramblay Y., Badi W., Driouech F. El Adlouni S., Neppel L., Servat E. 2012. Climate change impacts on extreme precipitation in Morocco. Global Planetary Change. Vol. 82–83 p. 104–114. DOI 10.1016/j.gloplacha.2011.12.002.

Tsakiris G., Nalbantis I., Vangelis H., Verbeiren B., Huysmans M., Tychon B., Batelaan O. 2013. A system-based paradigm of drought analysis for operational management. Water Resources Management. Vol. 27 p. 5281–5297. DOI 10.1007/s11269-013-0471-4.

Tsakiris G., Pangalou D., Vangelis H. 2007. Regional drought assessment based on the Reconnaissance Drought Index (RDI). Water Resources Management. Vol. 21. Iss. 5 p. 821–833. DOI 10.1007/s11269-006-9105-4.

van Rooy M.P. 1965. A rainfall anomaly index (RAI), independent of the time and space. Notos. Vol. 14 p. 43–48.

Vogt J.V., Somma F. 2000. Introduction. In: Drought and drought mitigation in Europe. Eds. J. Vogt, F. Somma. Springer Verl. p. 3–5. DOI 10.1007/978-94-015-9472-1.

Wilhite D.A. 2000. Drought as a natural hazard: Concepts and definitions. Chapt. 1. In: Drought: A global assessment. Drought Mitigation Center Faculty Publications. No. 69 p. 3–18.

Wilhite D.A., Glantz M.H. 1985. Understanding the drought phenomenon: The role of definitions. Water International. Vol. 10. Iss. 3 p. 111–120. DOI 10.1080/02508068508686328.

WMO 2006. Drought monitoring and early warning: Concepts, progress, and future challenges. Geneva. Switzerland. World Meterological Organization. ISBN 978-92-63-11006-0 pp. 24.

Zarei A., Asadi E., Ebrahimi A., Jafary M., Malekian A., Tahmoures M., Alizadeh E. 2017. Comparison of meteorological indices for spatio-temporal analysis of drought in Chahrmahal-Bakhtiyari province in Iran. Hrvatski meteorološki časopis. Vol. 52. No. 52 p. 13–26.