Variability of meteorological drought and some consequences on date palm cultivation in Biskra (Algeria)

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Abstract

Climate change threatens Algeria, like most countries in the world. This change accelerates and intensifies all climatic phenomena, causing extreme weather events. Drought, or water deficit, has a brutal impact on various aspects of life, whether ecological, environmental or economic, hence the need to analyze this natural phenomenon. In this context, this paper aims to analyze the meteorological drought in Biskra, south-east of Algeria, using five indices of drought: i) Rainfall Index, ii) Mean Deviation Index, iii) Standard Deviation Number Method, iv) Frequency Analysis, v) Standardized Precipitation Index. In general, the results obtained show a higher trend of dry years, despite the interannual variability between dry and wet years, with the recording of a drought sequence of five consecutive years. While the wet sequences did not exceed the three successive years. This variation, if associated with the lack of irrigation water and high temperatures, could reduce the quality and yields of dates, specifically ‘Deglet Nour’, which is a sensitive and demanding variety.

Keywords: Biskra, climate change, date palm (*Phoenix dactylifera* L.), indices of drought, meteorological drought, variability

Introduction

In the context of global climate change, like other countries around the world, Algeria will face multiple climate risks. According to the IPCC (2014), the risks of extreme weather events related to climate change such as heat waves, extreme precipitation and floods are already moderate (high confidence) and would reach a high level with an additional increase in the overall average temperature of 1°C (average confidence).

In the coming years, therefore, we can expect mixed situations of drought and rainfall surpluses. The consequence would be an increase in hydro-climatic disasters (IUCN, 2015).

However, these climatic hazards will be felt differently and their consequences will depend on several factors. In arid and semi-arid regions, the production systems and lifestyles of populations, mainly agro-pastoral, remain vulnerable to the vagaries of the climate. For example, the resurgence in recent years of extreme events such as droughts and floods, which are sometimes localized but very devastating, is likely to jeopardize the efforts of public authorities to achieve development objectives, particularly in the agricultural sector.

Drought is a prolonged period of precipitation deficits resulting in significant crop damage and a consequent loss of yield; it is one of the most catastrophic climatic hazards in terms of short- and long-term economic and social losses for millions of people worldwide. According to FAO (2015), drought-related damage and loss across all natural disasters is more than 15%, with droughts alone accounting for 85.8% of livestock losses. A single year of drought can delay years of social development. Water scarcity alone could cost some regions up to 6% of their GDP by 2050, triggering mass migration and resource-related conflicts (Safar-Zitoun, 2018).

Drought can have various aspects that vary depending on the type of resource affected by this natural phenomenon and the type of economic activity most affected. Different types of drought can be defined according to its characteristics, we quote among others: i) hydrological drought, ii) hydrogeological drought, iii) agricultural drought, iv) edaphic drought, v) socio-economic drought and vi) meteorological drought (Alouni and Louati, 1999; Dhaou, 2003). While the latter is the driving event of other types of drought (Dhaou et al., 2009).

Meteorological drought is the type of drought that occurs when precipitation is well below normal over a long period; it is a lack of natural water availability relative to its average value, and for a period long enough for the need to be felt. According to Dhar et al. (1979), a meteorological drought is when one has a shortage of 20% or more below the normal average of rains.

A drought associated with other climatic hazards such as heat waves, always plays a disruptive role and its impacts on economic sectors are often immediate. According to the Office for Climate Education (2019), if global warming reaches 2°C, it will cause a drought that will expose an additional 200 to 300 million people to water supply deficits. This deficit will be greater in the Mediterranean and South Africa. Populations directly dependent on agriculture will be among the most vulnerable.

The analysis of drought hazards in the Biskra region is an important and mandatory step that will enable decision-makers to make planning and territory development decisions taking into account drought risk, especially in a region where this hazard can condition all development efforts provided by the authorities.

Biskra is a potentially agricultural region, characterized by market-growing, fruit-growing and mainly by cultivation of date palm. It is the largest producer of dates in Algeria, both quantitatively and qualitatively. The Deglet Nour, characterized by its tenderness and golden appearance of the pulp, is the most dominant variety in this region, from the point of view of the number of palm (more than 2.6 million, of which 2.4 million in production), production (more 2.6 million quintals) and yield (110.3 kg/tree). Deglet Nour dates are marketable in all international markets, especially European markets. These fruits are practically the main agricultural product exported from Algeria (DSA-Biskra, 2018; Benziouche and Chehat, 2019; Fedala et al., 2020).

Good date production generally requires high temperatures, almost total absence of precipitation during certain stages of fruit development (in particular the ripening stage), low humidity, but also the presence of irrigation water during appropriate periods of the plant's vegetative cycle. Heavy and intense rainfall causes inflorescences to fall and spathe to rot at the flowering stage, pollen loss at pollination, and/or parthenocarpic fruit generation. During the ripening stage of the fruits, they cause the fall and decay of dates and sometimes the fermentation on the dates before the harvest; as was the case in 2008, in Biskra, where 30% of the production in quality was deteriorated as a result of the climatic hazards experienced by the region. For its part, the drought encourages the lowering of the water table and the salinity of the soils. It causes the shift of some phenological stages of the date palm, especially the maturation stage, which negatively affects the morphological and biochemical parameters of the dates. A dry period accompanied by high temperatures induces the drying of dates and/or early maturity and sometimes the development of pests, such as Boufaroua (*Oligonychus afrasiaticus*), which will decrease the organoleptic characteristics of this variety (Toutain, 1967; Benziouche, 2012; Amrani, 2018; Faci et al., 2020).

In addition, sheep farming, which characterizes much of southern Biskra, is based on pastoralism. As a result, fauna and flora are dependent on rainfall, which did not exceed an average of 139 mm per year. While irrigation water is insufficient on most farms (DSA-Biskra, 2018; Benziouche and Chehat, 2019).

This contribution aims to study the evolution of drought in Biskra, a region that has experienced a doubling of its palm date heritage during the last twenty years; in order to know the variation of this natural phenomenon during the period 1974-2018.

Materials and methods

Study region

Biskra is located in the southeast of Algeria (Figure 1), about 425 km from Algiers, and covers an area of 21,671.2 km^2. The wilaya (department) of Biskra is an important pole in the Algerian economic sector. It generates significant revenues through tourism, industry, trade and agriculture (DPSB-Biskra, 2019).

Climatic data

For this work, we used precipitation data recorded at the Biskra Meteorological Station, which depends on the National Meteorological Office (ONM), located about 8 km from the city of Biskra (34.80°N and 5.73°E) over an altitude of 87 meters (ONM, 2019). These are the monthly data for the period 1974-2018.

Figure 1. Administrative boundaries of the Biskra wilaya (in grey) on the map of Algeria.

Drought indices

Knowing the best drought index for a given climate and data application is an issue that has been the subject of much debate over the years. A number of definitions and indices of drought have emerged and some authors have attempted to provide informed opinions on the subject.

According to Safar-Zitoun (2018), the indices are most often numerical representations of drought intensity, which are calculated from climatic or hydrometeorological values. They measure the qualitative state of a drought at a given location for a given period. Technically, these indices are indicators. Information from the indices is useful for planning and designing applications (risk assessments, early warning systems and decision-making tools to mitigate the threat in the affected areas) provided the climate regime and climatology of droughts in the region is known.

The indicators can be classified into two categories: 1) local indicators based on point data and thus take on a meaning of "representative witnesses". 2) global indicators based on macroscopic and statistical data, significant at the level of administrative units (country, region, wilaya or common) or natural (watersheds, regional aquifers, agro-ecological zones) (Safar-Zitoun, 2018).

Since there is no single definition of drought, several drought indices are used worldwide, depending on the climate and the affected sector (WMO and GWP, 2016). The choice is often based on local habits, which in the long run become true customs (Koudamiloro et al., 2017). We used five indices, which are used for arid and semi-arid regions.

Rainfall Index (RI)

The index reflects the amount of precipitation received relative to the long-term average for a specified area and period. This is the ratio of the annual precipitation height (Pi) to the annual average precipitation height of the series (Pm) (Doukpolo, 2007).

$$\mathbf{RI = Pi / Pm}$$

A year is defined as wet if this ratio is greater than 1 and dry if it is less than 1 (Achir and Hellal, 2016).

To situate rainfall in a long series of rainfall surveys, the deviation proportional to the mean (RIm) is used.

$$\mathbf{RIm = RI - 1}$$

The accumulation of indices (RIm) over successive years makes it possible to identify the major trends without taking into account the small fluctuations from one year to the next. When the sum of the indices increases, it is a wet trend. The trend is “dry”, otherwise (Alouini and Bergaoui, 2001).

Mean Deviation Index (MDI)

This index is also called the ‘Drought Index’ (Doukpolo, 2007). This is the calculation of the difference between the annual precipitation height (Pi) and the annual average precipitation height (Pm). It is most commonly used by agrometeorologists to estimate the rainfall deficit on a year-round basis (Jouilil et al., 2013).

$$\mathbf{MD = Pi - Pm}$$

The annual distribution of rainfall provides direct information, on the fluctuation of rainfall heights and makes it possible, compared to the series average, to identify wet and dry years; also allows to estimate the rainfall deficit at the scale of the year and to visualize and determine the number of deficit years and their succession, This is referred to as a deficit year when rainfall is below average and a surplus year when the average is exceeded (TRIKI, 2009).

For wet years, the gap is positive and negative for dry years. We are talking about a deficit year when the rain is below the average and a surplus year when the average is exceeded. This index makes it possible to visualize and determine the number of deficit years and their succession (Alouini and Bergaoui, 2001).

Standard Deviation Number Method (SDNM)

It is calculated by comparing the annual average rainfall (Pm) to the number of standard deviations (σ) by the following formula (Aghrab, 2005):

$$\boldsymbol{\sigma = [1/(N - 1)]\Sigma(Pi - Pm)1/2}$$

When Pi (precipitation of the year calculated) is less than Pm – σ, it is called a strong drought. This is a very severe drought if Pi is less than Pm – 2σ (Alouini and Bergaoui, 2001) (Table 1).

Table 1. Severity of drought.

Type of drought	Comparison criteria
Moderate	Pm - σ < Pi < Pm
Strong	Pm- 2σ < Pi < Pm- σ
Very severe	Pi < Pm - 2 σ

Frequency Analysis (FA)

It is one of the basic tools for analyzing the occurrence of extreme events (Koudamiloro et al., 2017). In our case, the annual rains are ranked in ascending order according to their probability of non-exceeding (F) by the following formula:

$$\mathbf{F = (r / (N + 1))*100}$$

With:

r: ranking of the year according to a growing classification of rainfall quantities.

N: number of years of observation.

According to Alouini and Bergaoui (2001), the years will be classified according to their probability of non-exceeding into five classes as shown in Table 2.

Table 2. Drought classes according to frequencies (F).

Class	Frequency or probability at non-exceeding
Very dry	F < 15 %
Dry	15 % ≤ F < 35 %
Normal	35 % ≤ F < 65 %
Humid	65 % ≤ F < 85 %
Very humid	F ≥ 85%

Standardized Precipitation Index (SPI)

This is a probability index based only on precipitation. The probabilities are standardized so that a SPI of 0 indicates a median precipitation amount (relative to a 30 years average reference value). The index is negative for droughts, and positive for humides conditions. The World Meteorological

Organization (WMO and GWP, 2016), recommends the use of SPI as a starting point for monitoring meteorological drought, as it has a certain level of rapid drought warning. This precipitation index was developed in 1993 to quantify the precipitation deficit for multiple time scales that will reflect the impact of drought on the availability of different types of water resources over a given period of time (Mckee et al., 1993; Hayes, 1996). Its calculation does not require long rainfall series and has the great advantage of operating at various time scales and allowing for short, medium or long term drought assessments (Triki, 2009). This index is calculated, especially when precipitation is not normally distributed. It is expressed mathematically as follows:

$$\mathbf{SPI = (Pi - Pm)/s}$$

Pi: Rains of the year i.

Pm: Average rainfall of the series on the time scale considered.

s: Standard deviation of the series on the relevant time scale.

The calculation of the SPI at any location is based on the long-term precipitation history corresponding to the time period studied. A probability distribution is adjusted to this long series of surveys and then converted into a normal distribution, so that the mean SPI for the location and period is zero (Edwards & Mckee, 1997).

According to WMO (2012), we will use the classification system presented in Table 3, to define the intensity of drought episodes based on the index value.

Table 3. Values and meanings of the SPI.

SPI value	Meaning
2.0 and above	Extremely humid
From 1.5 to 1.99	Very humid
From 1.0 to 1.49	Moderately humid
From -0.99 to 0.99	Close to normal
From -1.0 to -1.49	Moderately dry
From -1.5 to -1.99	Very dry
-2 and less	Extremely dry

Results

Rainfall Index (RI)

Analysis of the rainfall data recorded at Biskra, by the rainfall index, clearly shows the interannual variation between dry and humid years (Figure 2). Until the first half of the 1990s, the number of dry years was the highest. While the highest number of wet years is recorded in the last decade of the series (last six years).

The overall trend is slightly dry (23 years), with a dry sequence of five consecutive years (1981-1985). On the other hand, humid sequences are short-lived; only three years (1975-1977, 1990-1992 and 2003-2005).

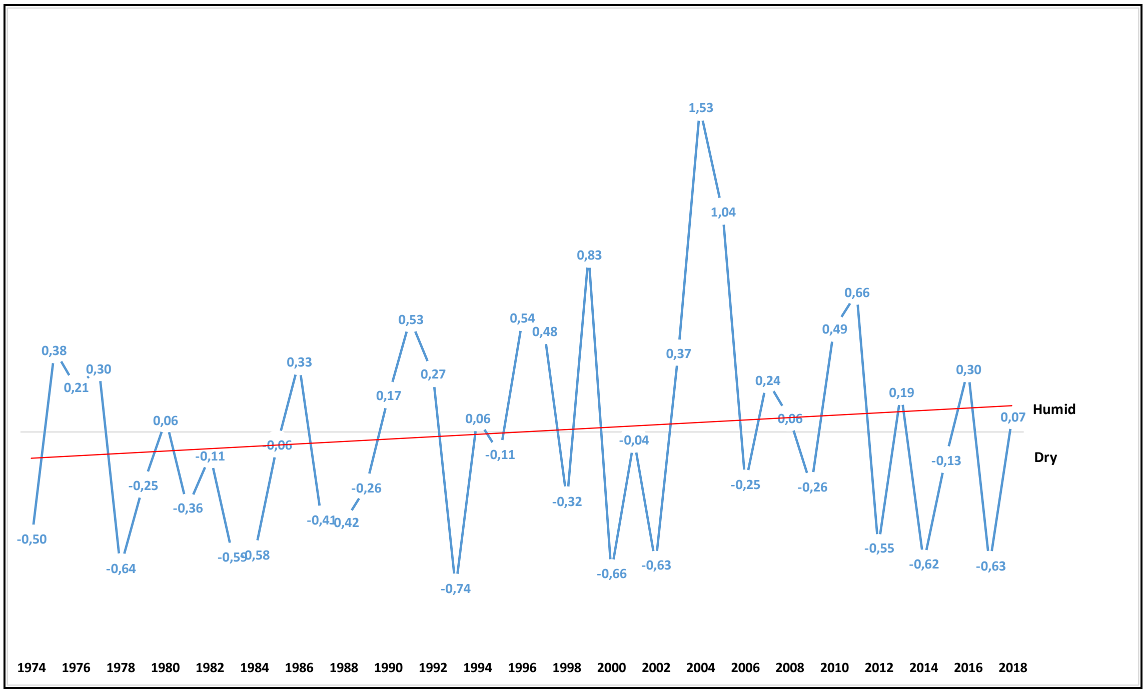

Figure 2. Results of the analysis of the rainfall index in Biskra.

Mean Deviation Index (MDI)

The calculation of the mean deviation index shows the number of humid or surplus years and the number of dry or deficit years. According to Triki (2009), we consider a deficit year when rainfall is below average, while a surplus year is when accumulation is above average.

The analysis showed that there is reconciliation between the number of surplus and deficit years; 22 and 23 consecutive years (Figure 3).

Three long dry sequences were recorded, one of five years and two of three years (1981-1985, 1987-1989 and 2000-2002, respectively). The same applies to humid sequences, that is to say three sequences, but for duration of three consecutive years for each one (1975-1977, 1990-1992 and 2003-2005).

For the sequences of two successive dry years, these are two (1978-1979 and 2014-2015). However, there are three humid sequences (1996-1997, 2007-2008 and 2010-2011).

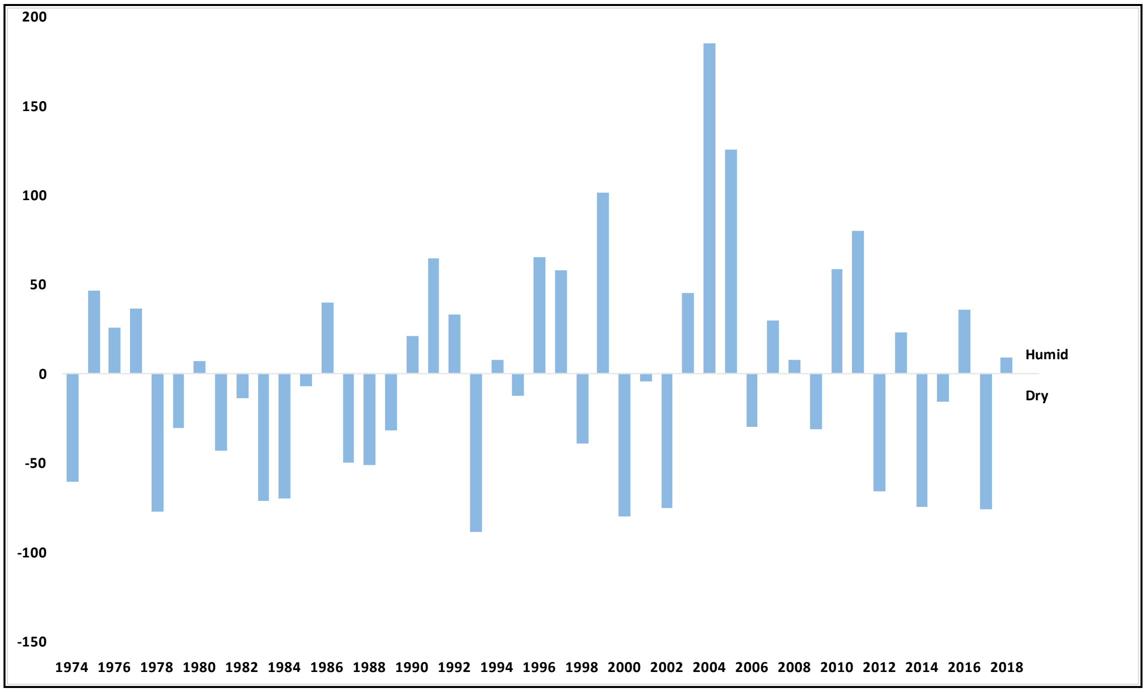

Figure 3. Results of the analysis of the mean deviation index in Biskra (mm).

Standard Deviation Number Method (SDNM*)*

In order to measure the severity of the drought experienced in the study area, we used the criterion of comparison to mean and mean minus one or two standard deviations. Thus, the graphic representation (Figure 4) allowed us to distinguish that 51.11% of the years in the series are years of drought; spread over 31.11% of years of moderate drought and 20% of years of severe drought.

Frequency Analysis (FA)

Of the 45 years of observation, the analysis shows that 16 years are dry and very dry, or 35.55% of the years in the series are deficient. While 13 years are normal, and 16 years are humid and very humid, representing 35.55% of surplus years (Figure 5).

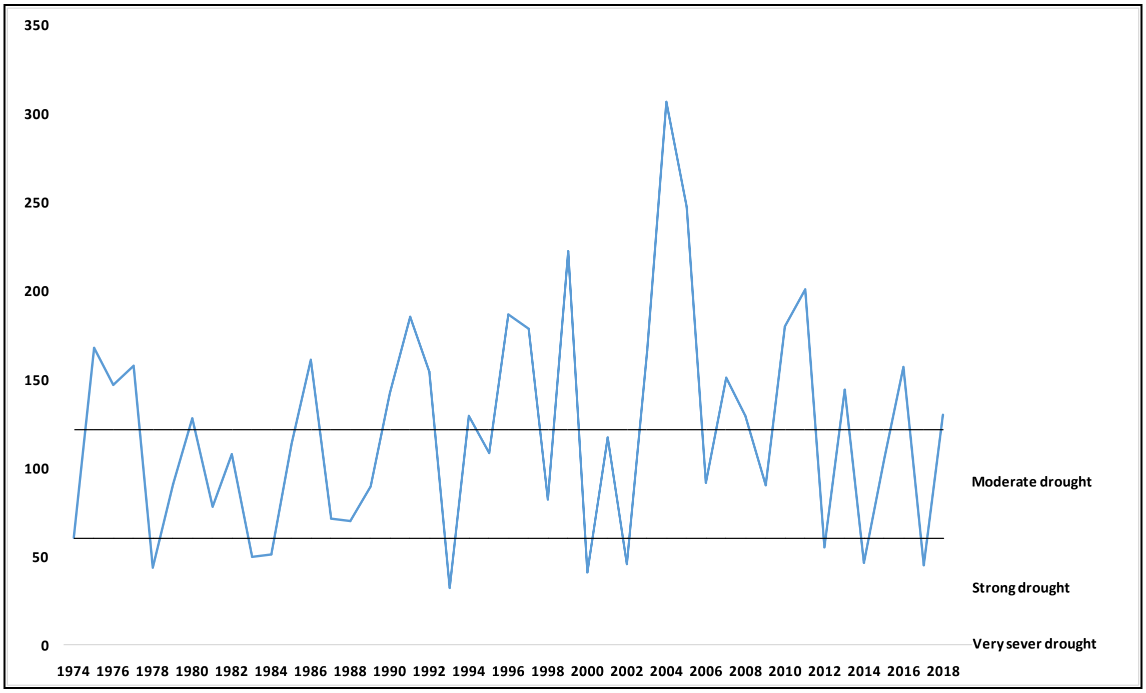

Figure 4. Results of the analysis of the standard deviation number method in Biskra (mm).

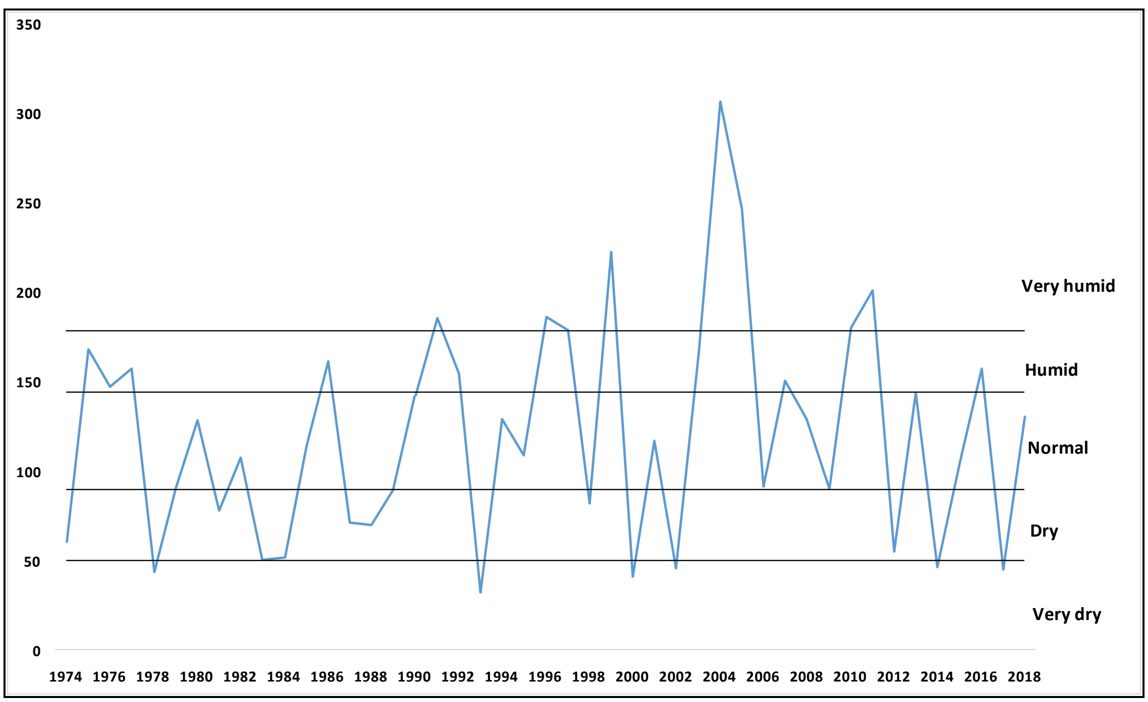

Figure 5. Results of the frequency analysis in Biskra (mm).

Standardized Precipitation Index (SPI)

The SPI analysis (Figure 6) showed that: 80% of the period studied is close to normal, while 8.88% of the years are moderately dry and 4.44% are very dry. While the total of the humid years is only 6.67% of the years in the series; divided into three classes: extremely humid, very humid and moderately humid, with a rate of 2.22% for each class.

The most humid year was 2004, while the two very dry years, 1979 and 1984.

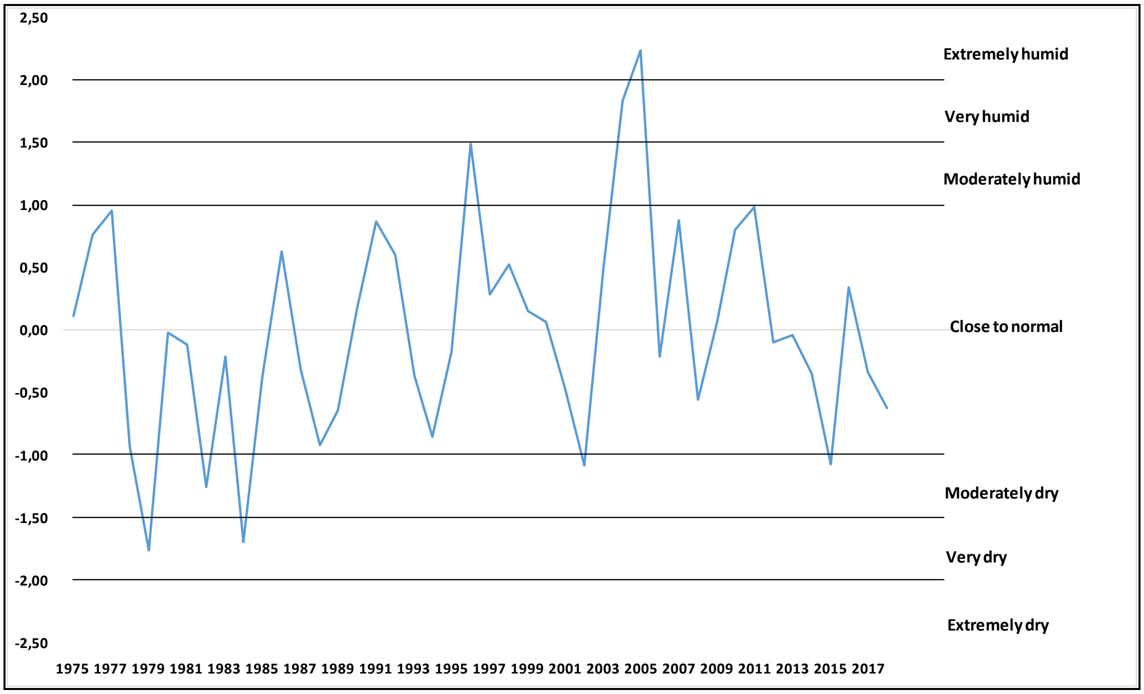

Figure 6. Results of the standardized precipitation index in Biskra.

Comparison between dry and humid years repeatability

The data series analyzed is 45 years (1974-2018). The five indices were used to characterize the year accumulation precipitation relative to the average and other years in the series, whether they were dry or humid years. The standard deviation number method a makes it possible to specify the drought class (moderate, strong or very severe), while the frequency analysis and the normalized precipitation index gave the possibility to classify all years, whether for dry or humid years. The latter two indices presented an intermediate class; ‘Normal’ for frequency analysis and ‘Close to normal’ for SPI.

In general, there is an approximation between the number of dry years and the number of humid years, but with a slight tendency towards dry years (Table 4).

Table 4. Comparison between the number of dry and humid years.

Indices	Number of years	
	Dry	Humid
Rainfall Index	23	22
Mean Deviation Index	23	22
Standard Deviation Number Method	23	22
Frequency Analysis	16	16
Standardized Precipitation Index	6	3

Discussion

From a meteorological point of view, drought is a recurring natural phenomenon of the climate, which characterizes a period, during which the lack of water seriously disturbs the hydrological balance of a region (Huschke, 1959; Rossi, 2000). According to Matari (1997), Algeria experienced three major droughts during the twentieth century, which resulted in a rainfall deficit in the country.

The analysis of precipitation data on Biskra by five meteorological drought indices, namely: the rainfall index, the mean-deviation index, the number of standard deviations index, frequency analysis and standardized precipitation index; The analysis revealed the inter-annual variability between dry and humid years, which characterized the period from 1974 to 2018.

The rainfall index and mean deviation index analysis resulted in a slight dry trend in the region, with 23 dry years. However, the number of humid years has increased over the last 15 years of the data series.

The severity of a drought is felt all the more if the year in question followed one or more dry years. A sequence of successive dry years is of course more severe than isolated drought (Benzarti, 1990). The number of dry sequences at Biskra was 5, while the humid sequences are 6. The longest sequence was dry, with duration of five successive years (1981-1985), while the remainder of sequences is three and two consecutive years. Humid sequences were recorded in 1975-1977, 1990-1992, 1996-1997, 2003-2005, 2007-2008 and 2010-2011; while dry sequences were recorded in 1978-1979, 1987-1989, 2000-2002 and 2014-2015.

The index of the number of standard deviations allowed knowing the severity of the drought in Biskra, where we recorded 14 years of moderate drought and 9 years of strong drought.

To determine the precipitation class for each year, we are used the standardized precipitation index and frequency analysis. The latter results from the recording of 8 humid years, 8 very humid years, 10 dry years and 6 very dry years. While the SPI allowed observing one moderately humid year, one very humid year, one extremely humid year, 4 moderately dry years and 2 very dry years; this shows that the record of dry years is higher than the number of humid years.

The spatial extent and the gradual and largely unpredictable onset of drought have a visible negative effect on population, harvest, livestock, pastures, forests and water resources (Dhaou et al., 2009).

The probability of drought in Algeria during the 21st century is high (Matari, 1997). WMO (2020) predicts a decrease in precipitation in the Biskra region. A reduction in precipitation associated with a trend towards higher maximum and minimum temperatures will increase the salinity of aquifers and land, factors that increase the net irrigation water needs of date palms during this future period (Haj-Amor et al., 2020). Therefore, the inter-annual variation and intensity of drought in the region of this study must be monitored on a permanent basis; because a simple water deficit can have a negative effect on flora and fauna, as well as on agriculture and livestock. Especially since Biskra is known by these 'Deglet Nour' dates, which may lose their Protected Geographical Indication (PGI) label, following a presumed degradation of fruit quality; which will have a negative impact on the commercial and economic value of this famous product. This possibility is imminent, since the inter-annual variation between dry and humid years is permanent.

Despite the absence of records of "very severe" drought periods during the last 45 years, the continuous alternation between humid and dry sequences will have an influence on date palm productivity; especially during dry sequences of several successive years. This will lead to an excessive demand for irrigation water, favour the appearance of diseases and pests, as well as the drying out and degradation of the physico-chemical components of the fruits.

Conclusions

Drought in Biskra has a direct effect on date production. It may be fatal on the 'Deglet Nour', which is a late variety; requires more time to ripen, compared to other varieties, until the end of November. In order to avoid this impact, additional doses of irrigation water should be applied during dry periods, especially in summer (warm period in Algeria) which coincides with the phenological stage of fruit maturity. As it is necessary to install permanent programs of phytosanitary monitoring and control, to limit the spread of diseases and pests. In addition, it is necessary to apply and develop the covering technique of date diet, in order to protect the fruits and to minimize evapotranspiration.

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