*Algerian Journal of Environmental Science and Technology*
*December edition. Vol.5. Nº3. (2019)*
*ISSN : 2437-1114*
*www.aljest.org*

# Analysis of Climatic Drought using Drought Indices in Algiers Region

H.Ladji*, K.Benrachedi, S.Djoumad

Research Laboratory of Food Technology, Faculty of Engineering Sciences, M'Hamed Bougara University, Boumerdes 35000, Algeria.

*Corresponding author: h.ladji@univ-boumerdes.dz; hladji@yahoo.fr; Tel.: +213 00 00 00; Fax: +21300 00 00

## ARTICLE INFO

***Article History:***

*Received* ***: 29/11/2018***
*Accepted* ***: 24/04/2019***

***Key Words*:**

*Drought;*
*drought indices;*
*rainfall;*
*precipitation shortage;*
*Algiers.*

## ABSTRACT/RESUME

***Abstract:****Our research consists on the one hand to study the evolution of the rainfall data and the annual and monthly temperatures observed in the Algiers region and on the other hand to analyze the sequences of the climatic drought in using statistical methods such as drought indices. The statistical study of rainfall series in the Algiers region reveals a large variation of the wet and the dry years in space and time. The series of measurements of 1967-2015 are repeated in years of drought (moderate or high). Indeed, the last three decades (1980, 1990 and 2000) are particularly concerned by this situation of annual rainfall deficit.*

## I. Introduction

Since the 1990s, the notion of climate change has been debating water resources and the risks associated with them by placing them at the very heart of the problem [1]. Climate change will affect water resources through its impact on the quantity, variability, weather, form and intensity of precipitation [2].
Algeria is one of the African countries that suffers from water shortages from one season to another and from one year to the next [3], in the category of the poorest countries in terms of water potential [1], below the theoretical threshold of scarcity set by the World Bank at 1000 $m^3$ per inhabitant per year [4]. The country's water resources are largely dependent on very irregular and unevenly distributed rainfall [5].
In most of Africa, drought is the most frequent climatic disaster. Drought is one of many natural disasters that develops slowly [6, 7]; It is a recurrent climatic event occurring in the world and strongly perceived by Mediterranean countries [8]. Algeria, as one of the Mediterranean countries mainly located in semi-arid and arid areas, has been confronted with periodic droughts that are sometimes severe and persistent [9], during the 1940s and 1970s to the present day [10]. The most recent has been characterized by its spatial scale and intensity [11].
Drought is one of the natural disasters that disrupts the water supply of natural and agricultural ecosystems and other human activities [12, 13]. Of all natural disasters, drought causes the greatest damage [14]. It has no universal definition [15, 16], there are as many definitions of drought as there are of water use [17]. Drought is a dry weather character, which directly influences the terms of the need-resource balance. It can occur at any time and at different scales (season, year, and decade) [18]. Wilhite and Glantz in 1985 [19] define drought as a water deficit of at least one component of the hydrological cycle. There are traditionally three types of drought [20, 21]: meteorological droughts linked to a deficit in cumulative rainfall, hydrological droughts linked to river flows or groundwater levels and agricultural or soil droughts that describe the effect of the first two types of drought on agricultural production [3]. These types of drought may not occur simultaneously, but meteorological drought remains the driving force behind the others [18]. The meteorological drought that is the subject of our study is due to natural reduction or poor distribution or even absence of precipitation over a given region for one or more successive years [17, 21-23]. It is often defined by

the difference between annual rainfall and average annual rainfall.
The persistent drought that Algeria has suffered for several decades [24] has been the subject of several scientific articles, indeed, most or all of the research on drought and climate change in Algeria has been based on the northwestern part of the country [10, 11, 29-32].
The Algiers region in central northern Algeria has suffered greatly in recent decades from water shortages, which have been exacerbated by rising global temperatures and significant reductions in rainfall. However, we have not found any recent and in-depth scientific work addressing these worrying precipitation deficits. In order to prevent extreme meteorological events, we propose to carry out an in-depth analysis of the annual and monthly rainfall and air temperature data observed in the Algiers region (Algiers catchment area) on the one hand and to identify the characteristics of meteorological drought and to highlight deficit and surplus years on the other hand.

## II. Methodology

### II.1. Presentation of the study area

The Wilaya of Algiers belongs to the sub-basin of the Algiers in the North of Algeria at an altitude varied between 2m and 424m, it covers an area of 12 463 Km2 or 26.28% of the total area of the Algiers-Hodna-Soummam basin [29].
The climate is of a moderate Mediterranean type [24]. It has low thermal amplitude. The average annual temperature varies between 16/18°C with average summer temperatures of about 24°C and average winter temperatures around 11°C, with the average annual maximum and minimum monthly temperatures being 22°C and 11°C respectively [30]. Interannual rainfall ranges from 670 to 800 mm/year with an exceedance of 100 mm/year in November, December and January [31].
Humidity is moderate throughout the year with an average value of 68%. The wind speeds are generally moderate around 2 m/s but the sirocco present in the area can have some harmful effects. The average duration of sunshine in Baraki is about 2,650 hours per year. The reference evapotranspiration (ETU) estimated by the Penman formula is 1,189 mm/year at Baraki, with the highest values occurring from May to September [30].

### II.2. Data (choice of stations and study period)

Climate events in a region can be analyzed using various indices, which use all precipitation either alone or in combination with other weather elements, depending on the type of requirements [23].
The climatic data used in this study are rainfall and air temperature. They come from the directories of the two organizations responsible for the rainfall network, namely the National Agency for Water Resources (N.A.W.R.) and the National Meteorological Office (NMO).
Precipitation is the major element in studying the temporal and spatial variability of drought [32]. They are easy to measure. For these reasons, most studies and analyses focus on precipitation much more than on other climate parameters [33].
The problem with rainfall data in Algeria is the lack of professional stations; the rainfall data provided by the National Hydraulic Resources Agency have occasional shortcomings due, in most cases, to an interruption in meteorological observations due to the absence of the observer. After criticism and homogenization of the data, we are satisfied to retain 04 rainfall stations (Table 1) for our study with long observation series and a minimum of gaps. Missing data are replaced by data from the nearest stations with the same climatic conditions and located in the same study area (Figure1).
The annual precipitation of the stations studied (Bir Morad Rais, Baraki, Mahelma, Dar El Beida) covers the periods 1967-2009, 1972-2010, 1970-2012 and 1967-2015 respectively. These data are of good quality and representative of the study area. In addition, the temperature series provided by the NMO for the Dar El Beida station cover the period 1971 to 2015.
The choice of stations and observation periods for air temperature and precipitation data was made according to the availability of these data at the level of the National Meteorological Office and the National Hydraulic Resources Agency.

### II.3. Drought methods and indices used for drought analysis

Drought is difficult to monitor and many indices and statistical methods have been proposed to characterize and identify climate drought and assess rainfall trends [19, 21, 34-37]. The choice of indices depends on their reliability to provide results and data availability, for our study we opted for the choice of the two indices: the Standardised Precipitation Index (SPI) and the percent to normal index (PNI). According to several studies and the results of the National Workshop (Medenine, December 25, 2006), these indices are the most reliable and best adapted to Mediterranean and Maghreb conditions [38, 39].
The indices used in this study make it possible to determine the threshold of climate drought, to establish a classification according to the severity of the event and its position and to identify the probability of occurrence of different severity classes.

#### II.3.1. The Standard Precipitation Index (SPI)

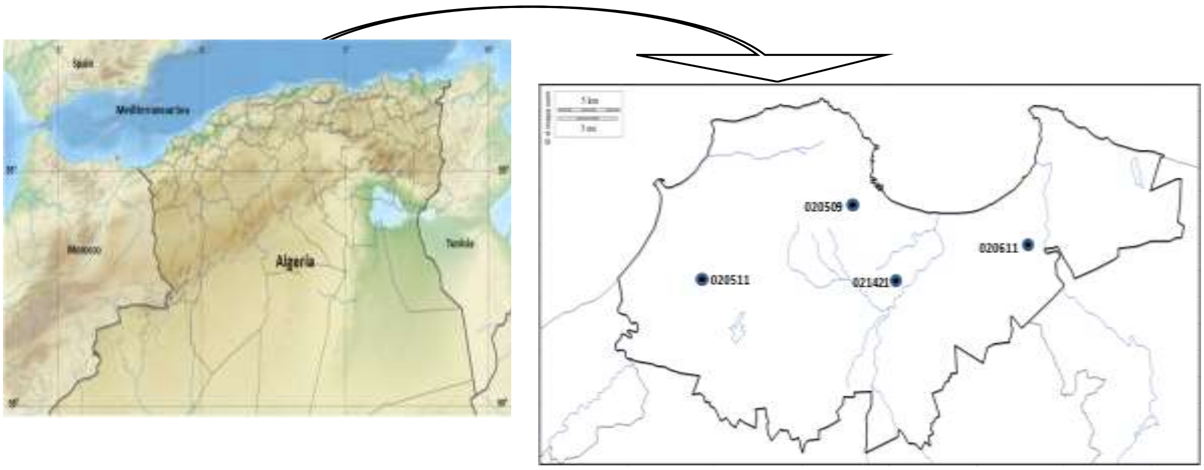
Worldwide, the Standard Precipitation Index (SPI) is the most widely used index for understanding the Magnitude and duration of drought events in both research and operational mode [40-42].

*Algerian Journal of Environmental Science and Technology*
*December edition. Vol.5. Nº3. (2019)*
*ISSN : 2437-1114*
*www.aljest.org*

***Table 1.*** *Characteristics of the climate stations used for this study*

| Nom et code de la station | | Alger Dar El Beida 020611 | Baraki 021421 | Bir Mourad Rais 020509 | Mahelma 020511 |
|---|---|---|---|---|---|
| Lambert system geographical coordinates | **X (Km)** | 547.35 | 535.05 | 531,1 | 517 |
| | **Y (Km)** | 379.6 | 376.5 | 382,8 | 376.85 |
| | **Altitude** (m) | 25 | 20 | 140 | 150 |
| Observation period | | 1940-2015 | 1972-2013 | 1968-2012 | 1971-2013 |
| Number of years studied | | 76 | 42 | 45 | 43 |
| Average rainfall (mm) | | 708.3 | 617.83 | 743.61 | 623.6 |
| Standard deviation | | 191.90 | 177.11 | 176.50 | 172.29 |
| Variation coefficient % | | 27.09 | 28.7 | 23.7 | 27.63 |

Legend: X : Longitude ; Y: Latitude




***Source: N.A.W.R***

***Figure1.*** *Location of of rainfall stations in study area*

The standardized rainfall index (SPI) was developed by McKee and al (1993) [40] in the USA to characterize rainfall deficits for a given period [43]**.** It can detect the beginning and end of drought, its duration, severity and magnitude [44]. Due to its simplicity, the SPI climate index is the most widely used internationally. It is based solely on rainfall data [45]and it takes into account the importance of time in analysing the availability of water resources [40]. It can be evaluated for durations of 1, 3, 6, 12, 24, 36, 48 months or even longer [43].

The mathematical formula of SPI is as follows:

SPI= (pi-pm)/σ

Pi: Precipitation of year i

Pm: Average precipitation of a long data series

σ : Standard deviation of annual rainfall.

To calculate the SPI, at least monthly rainfall readings over 20 to 30 years (preferably 50 to 60 years) are required [46]. The calculation of this index makes it possible to anticipate drought and helps to determine the severity of the drought [16] according to different classes (table 2).

The different severity classes established by Mckee in 1993 using the standard deviation number method can be arbitrarily defined by [40]. Taking into account the climatic characteristics of the study regions, several new SPI classifications have been created by different authors [47-49]. In 2003 Aghrab [50] modified the general classification of SPI proposed by Mckee 1993, taking into account the specificities of the Moroccan climate, and proposed a corrected SPI, better adapted to North African conditions. Given the similarity of the climate in Algeria and Morocco, we used this classification (Table 3). This method proposes to classify the years according to the SPI values.

***Table 2.****Climatic classification according to the SPI*

| SPI values | Class |
|---|---|
| > 2 | Extremely wet |
| 1.5 to 1.99 | Very wet |
| 1.0 to 1.49 | Moderately wet |
| -0.99 to 0.99 | Near normal |
| -1 to -1.49 | Moderately dry |
| -1.5 to-1.99 | Severely dry |
| < -2 | Extremely dry |

***Source:*** *McKee and al. 1993*[40]

***Table 3.*** *Classification of the SPI into climate classes according to Aghrab [50]*

| SPI value | Category | Probability (%) |
|---|---|---|
| ≥2 | Extremely wet | 2,3 |
| 1,00 to1,99 | Very wet | 13,6 |
| 0,31 to 0,99 | Moderately wet | 24,2 |
| -0,30 to 0,30 | Normal | 18,9 |
| -0,31 to –0,99 | Moderate drought | 24,2 |
| -1,00 to -1,99 | Severe drought | 13,6 |
| ≤-2.00 | Extreme drought | 2,3 |

According to Mckee 1993 [40], negative SPI values are deficit or drought years and positive values are surplus years.

**II.3.2. The percent to normal index PNI**

This indicator measures the deviation of precipitation over a period from the historical normal for that period in a given area. The normal is usually the average of the total precipitation over the period, calculated from about 30 years of data [51]. Very simple to use, this method is not suitable in cases where the spatial and temporal disparity of precipitation is too great [52].

This index also known as the rainfall deficit index, it makes it possible to visualize and determine the number of deficit years and their succession. It is expressed by:

$PNI(\%)=(Pi-Pm)/Pm\times100$

A year isconsidered as dry when this index is negative and wet when it is positive. The accumulation of the index of the percentage deviation from the normal for successive years makes it possible to identify major trends without taking into account small fluctuations from one year to the next. When the sum of the indices increases, it is a wet trend [53].

***Table 4.*** *Drought severity classes according to PNI*

| PNI Value | Drought intensity |
|---|---|
| 80-60% | Moderate drought |
| 60-40% | Dry year |
| <40% | Very dry year |

**III- Results and discussions**

**III.1. Evolution and trend of rainfall**

Temperatures and rainfall, parameters taken as climate classification criteria, are not sufficient to determine, or predict, the climate evolution of a particular hydrological unit. However, rainfall makes it possible to determine a trend in a regional regime on a very limited time scale. The fluctuations in average annual rainfall show that the maximum value of about 913.8mm was recorded in 1984, the minimum value of about 282.6mm was observed in 2000.

The time series evolution curves, coupled by the linear trend curve and the moving average curve calculated over 5 years, identify the highly random nature of the rain.

Figure 2 shows an interannual rainfall variability based on fluctuations between dry and wet years. As a result of this succession of deficit years and surplus years, periods of increase and the continuous decrease in rainfall are highlighted. It is also found that periods of decline are more continuous and sustained than periods of increase. In addition, the linear trend curve representing annual totals is decreasing everywhere across all measurement stations (Figure 2).

*Algerian Journal of Environmental Science and Technology*
*December edition. Vol.5. Nº3. (2019)*
*ISSN : 2437-1114*
*www.aljest.org*

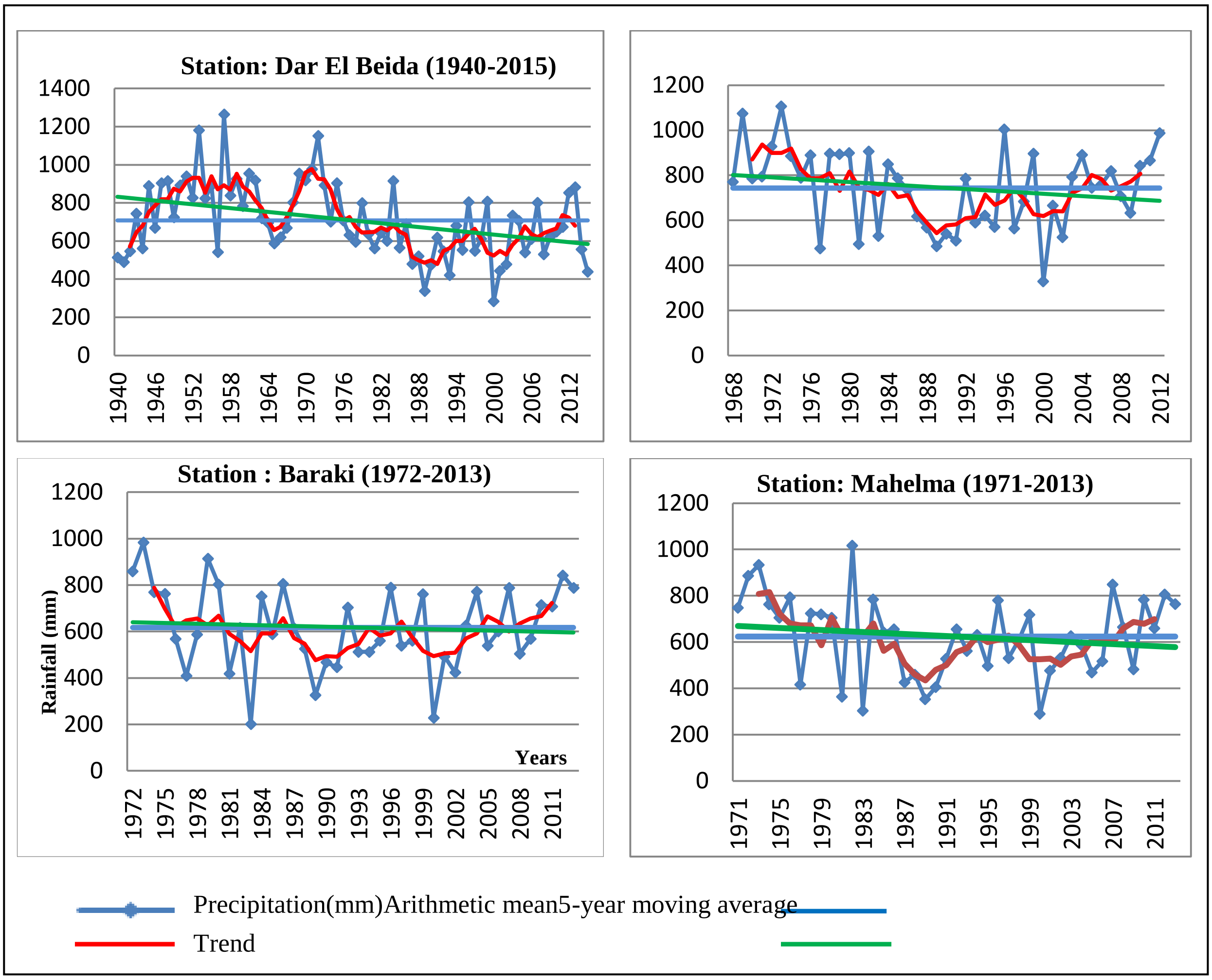



***Figure 2.*** *Interannual precipitation trends for Dar El Beida, Bir Morad Rais, Hamiz and Mahelma stations.*

### III.2.Temperature evolution

Temperatures are an important factor in determining the climatic characteristics of a region.

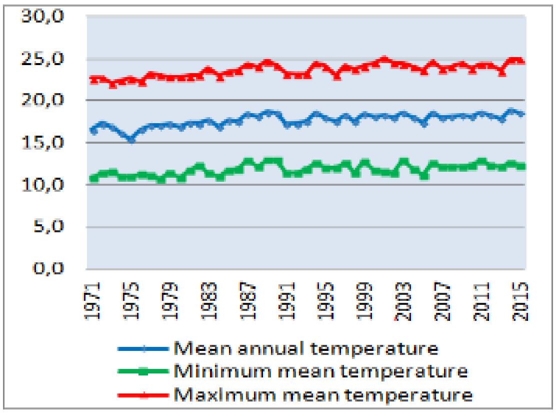



***Figure 3.*** *Mean annual temperatures (minimum and maximum mean) over the period 1971-2015 (Dar El Beida station)*

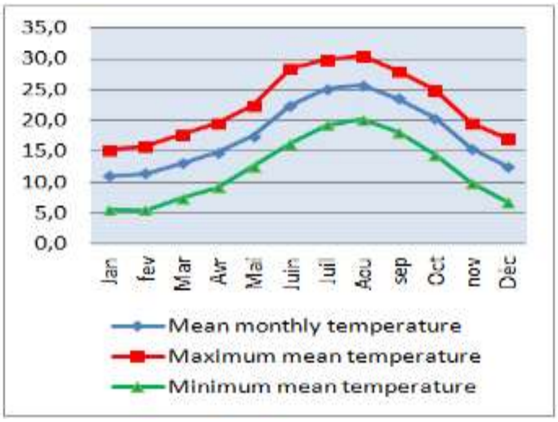



***Figure 4.*** *Mean monthly temperatures (minimum and maximum mean) over the period 1971-2015 (Dar El Beida station)*

The analysis of the mean annual temperature curves (Figure 3) of the Dar El Beida station over

the last few decades shows an upward trend in the Algiers region with little variation from one year to the next.
The mean annual temperature is 18°C. The results of this analysis correspond perfectly to the climate of northern Algeria, mainly Mediterranean [3, 54].
We observe:

- ➢ A cold period from November to April with average temperatures > 10°c, January being the coldest month with an average temperature of 11.0°c (figure 4).
- ➢ A hot period from May to October with an average temperature above the annual average, August being the hottest month with an average temperature of 25.7°c (figure 4).

### III.3. Calculation of drought indices

Statistical analysis of precipitation based on a few indices is recognized as effective in characterizing drought. To do this, we use in our study the most commonly used indices in Algeria [3] which are the standardized rainfall index (SPI) and the deviation from normal index (PNI) (Figures 5 and 6).

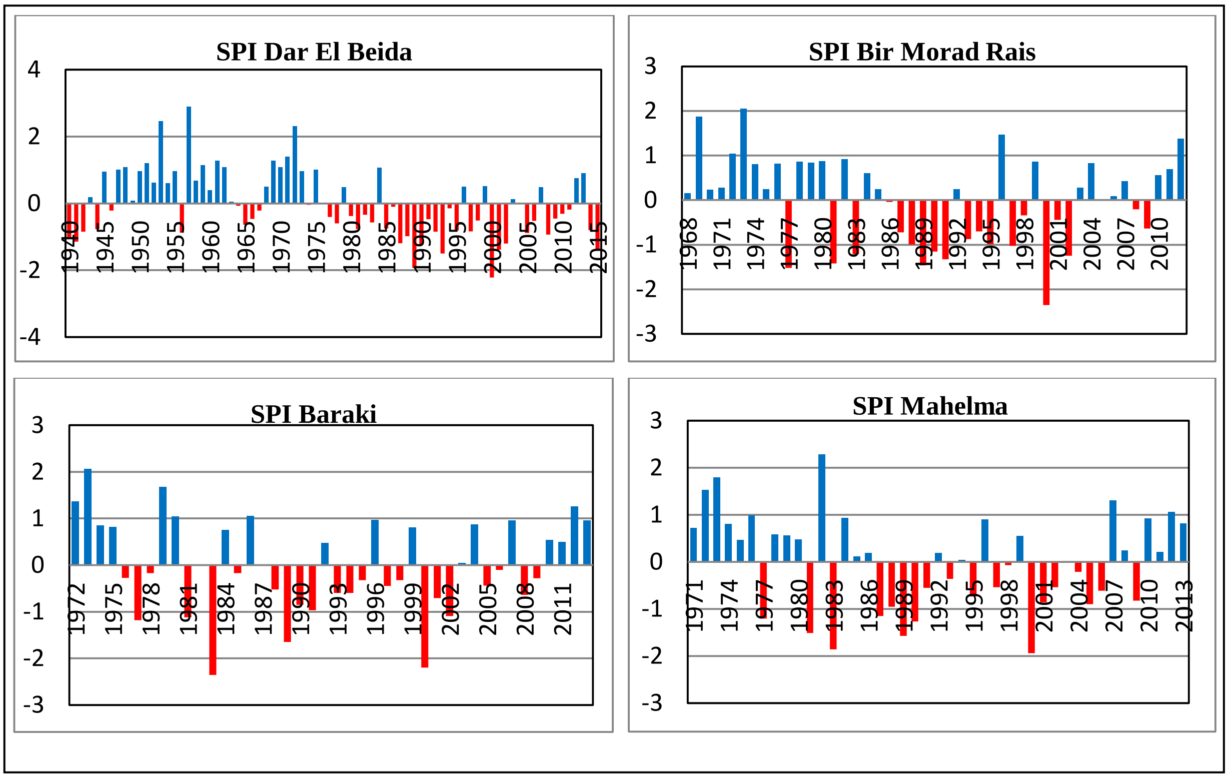



***Figure 5.*** *Standardized precipitation indices for the four stations*

The rainfall data recorded at the workstations, through the standardized rainfall index, characterize a situation mainly dominated by moderate drought and to a lesser extent severe drought (Table 3). In our study area years of extreme drought and extreme humidity are almost rare, they do not exceed 2% over the period 1940-2015.
At the temporal scale, the standardized precipitation index, indicating the still irregular nature of rainfall, nevertheless highlights wet and dry episodes (Figure 5). For all stations, drought trends have been significantly greater in recent decades (Figure 5).
It appears from this analysis that the decade 1967-1978 is in surplus. The last three decades 1979-2009 appear to be in deficit.

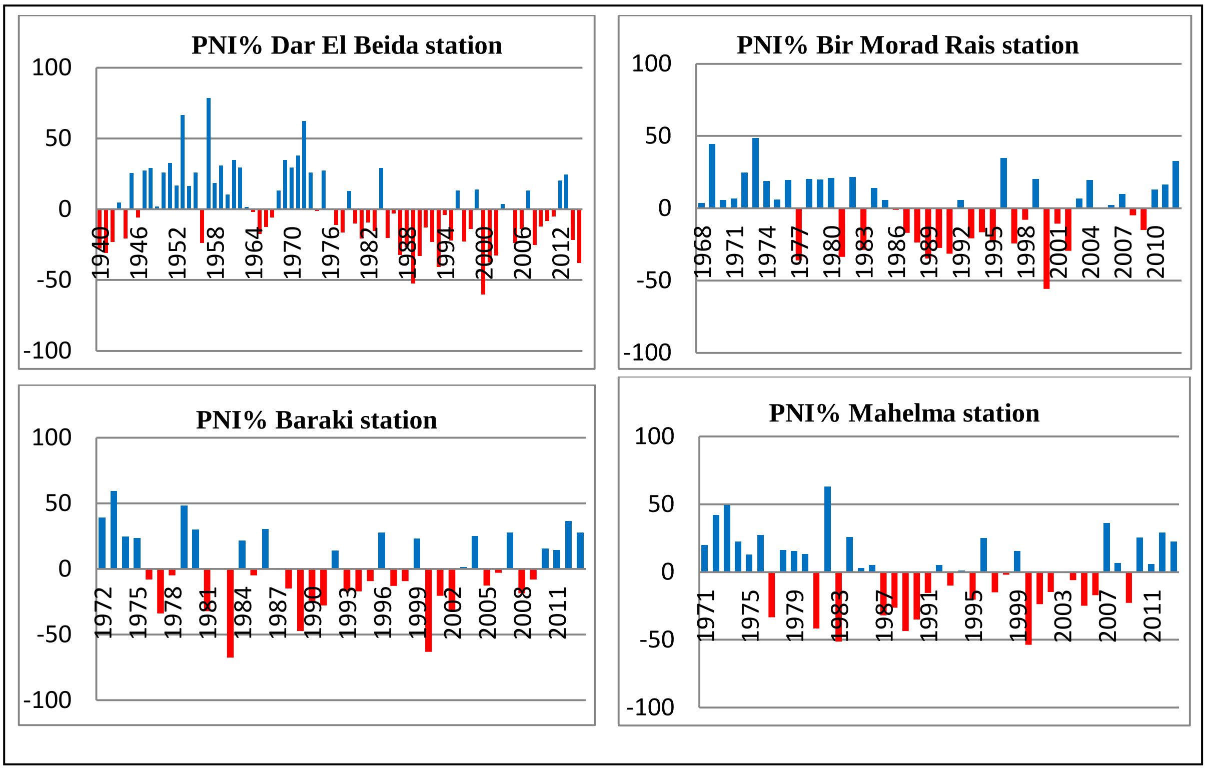



*Figure 6.* Index of deviation from normal (PNI) for the four stations

***Table 5.*** *Frequency of different drought and humidity classes*

| The qualifier | Dar El Beida (1940-2015) | | Bir Morad Rais (1968-2012) | | Baraki (1972-2013) | | Mahelma (1971-2013) | |
|---|---|---|---|---|---|---|---|---|
| | Number of years | % | Number of years | % | Number of years | % | Number of years | % |
| EH | 3 | 4,8 | 1 | 2,9 | 1 | 2,9 | 1 | 2,9 |
| HH | 11 | 17,5 | 4 | 11,8 | 5 | 14,7 | 4 | 11,8 |
| MH | 15 | 23,8 | 12 | 35,3 | 11 | 32,4 | 12 | 35,3 |
| MD | 24 | 38,1 | 7 | 20,6 | 11 | 32,4 | 10 | 29,4 |
| HD | 9 | 14,3 | 9 | 26,5 | 4 | 11,8 | 7 | 20,6 |
| ED | 1 | 1,6 | 1 | 2,9 | 2 | 5,9 | 0 | 0,0 |
| total | 63 | 100,0 | 34 | 100 | 34 | 100 | 34 | 100 |
| Wet year | 29,00 | 46,03 | 17,00 | 50,00 | 17,00 | 50,00 | 17,00 | 50,00 |
| Dry years | 34,00 | 53,97 | 17,00 | 50,00 | 17,00 | 50,00 | 17,00 | 50,00 |

EH: Extreme humidity; HH: High humidity; MH: Moderate humidity; MD: Moderate drought; HD: High drought; ED: Extreme drought.

The maximum percentage of drought years going up to 54% at Dar El Beida station including 38% years of moderate drought and 14% years of severe drought.

The dry sequences in Dar El Beida station are significantly longer than the wet sequences. For the other stations studied, the dry and wet sequences are almost the same (Table 5). The difference between the results of the four stations is that Dar El Beida is a professional station with long, reliable and good quality rainfall series. On the contrary, the other three stations are automatic and suffer several errors in weather observations.

**Table 6.** *Deficit and surplus years*

| | Dar El Beida (1940-2015) 76 years | Bir Morad Rais (1968-2012) 45 years | Baraki (1972-2013) 42 years | Mahelma (1971-2013) 43 years |
|---|---|---|---|---|
| **Years of EH* et HH** | 1947 ; 1948 ; 1951 ; 1953* ; 1957* ; 1959; 1961; 1962; 1969 ; 1970; 1971; 1972*; 1975; 1984. | 1968; 1971; 1972*; 1995 | 1972; 1973*; 1979; 1980; 1986; 2012. | 1972; 1973; 1982*; 2007; 2012. |
| **Years of HD et ED*** | 1940; 1941; 1987; 1989; 1990 ; 1993 ; 2000*; 2001; 2002; 2015 | 1977; 1981; 1983; 1988; 1989; 1990; 1991; 1997; 2000*; 2002 | 1977; 1981; 1983*; 1989; 2000*; 2002 | 1977; 1981;1983; 1987; 1989; 1990; 2000. |

The most persistent droughts have occurred over the past 25 years, consisting of three, four, five and seven years (Dar El Beida station).

Deficits recorded during the years of severe droughts (1979-2002) reached -63% in 2000 at Baraki station (Figure 4). The drought of 2000 is considered extreme for the entire Algiers region and caused very significant rainfall deficits in all the stations studied (-60% in Dar El Beida, -56% in Bir Mourad Rais, -63% in Baraki and -54% in Mahelma) with an average deficit of 58%.

## IV. Conclusion

This study made it possible to characterize the meteorological drought in the Algiers region for the period 1940-2015. The analysis of the graphs relating to the distribution of annual precipitation over the period 1940-2015 shows an alternation of dry and wet periods of varying duration from one station to another.

The evolution curves of the rainfall series, combined with the linear trend curve and that of the moving average calculated over 5 years, show a clear downward trend in rainfall. It is also noted that the periods of decline, which began in the early 1974s, are more continuous and sustained than periods of increase. The surplus years are mainly before 1974 and the deficit years are mainly after 1974.

The analysis of the annual and monthly average temperature curves of the Algiers station over the last few decades shows an upward trend in the Algiers region with little variation from one year to the next.

The rainfall data recorded at the four workstations, through the standardized rainfall index, characterize a situation mainly dominated by moderate drought and to a lesser extent severe drought. The maximum percentage of drought years going up to 54% at Dar El Beida station including 38% years of moderate drought and 14% years of severe drought.

In our study area years of extreme drought and extreme humidity are almost rare, they do not exceed 2% over the period 1940-2015. The most persistent droughts have occurred over the past 25 years, consisting of three, four, and five years and deficits recorded during the years of severe droughts (1976-2001) ranging up to -63% at the Baraki station.

## V. References


1. Nichane, M.; Khelil, M.A. Changements climatiques et ressources en eau en Algérie vulnérabilité, impact et stratégie d'adaptation. *Larhyss Journal* 21 (2015) 15-23.
2. Richard, M. A.;Peck, D. E. Effects of climate change on Water Resources. *Choices 23, The magazine of food, farm, and resource issues, 1st Quarter* (2008) 12-14.
3. Meddi, H.; Meddi, M.; Assani, A.A. Study of Drought in Seven Algerian Plains. *Arabian Journal for Science and Engineering* 39 (2014)339-359.
4. Benzerti, Z., Habaieb, H. Etude de la persistance de la sécheresse en Tunisie par utilisation des chaînes de Markov (1909-1996). *Sécheresse 12(2001) 215-220.*
5. Hassini, N. ; Abderrahmani, B.; Dobbi, A.Trends of Precipitation and Drought on the Algerian Littoral: Impact on the Water Reserves. *International Journal of Water Resources and Arid Environments,* 1(4) (2011) 271-276.
6. Salas, J.D. State of the art of statistical techniques for describing drought characteristics. *WARRDCC, International Seminar on Drought Analysis*. Italy, (1986).
7. Cao, Y.; Nan, Z.; Cheng, G. GRACE Gravity Satellite Observations of Terrestrial Water Storage Changes for Drought Characterization in the Arid Land of Northwestern China. *Remote Sens 7 (2015) 1021-1047*.
8. Pereira , L.S.; Cordery,I.; Iacovides, I.*Coping with water scarcity: Adressing the challenges*; Springer, Dordrecht, London, (2009) 382.
9. Boudjadja, A.; Messahel, M.; Pauc, H. Ressources hydriques en Algérie du Nord. *Journal of Water Science 16 (2003) 285-304.*
10. Meddi, M. ; Hubert, P. Impact de la modification du régime pluviométrique sur les ressources en eau du Nord-Ouest de l'Algérie. *Hydrology of the Mediterranean and semiarid Regions, IAHS 278 (2003) 1-7.*
11. Meddi, H. ; Meddi. M. Etude de la persistence de la sécheresse au niveau de sept plaines algériennes par utilisation des chaines de Markov (1930-2003). *Courrier du Savoir 9 (2009) 39-48.*

12. Pereira, L.S.; Cordery, I.; Iacovides, I.*Coping with Water Scarcity*. UNESCO IHP VI, Technical Documents in Hydrology No. 58, UNESCO, Paris, (2002) 267.
13. Shatanawi, K.; Rahbeh, M.; Shatanawi, M. Characterizing, Monitoring and Forecasting of Drought in Jordan River Basin. *Journal of Water Resource and Protection 5(2013) 1192-1202.*
14. Wilhite, D. A**.** Chapter 1 Drought as a natural hazard: concepts and defnitions, in *Drought, A Global Assessment;* Drought Mitigation Center Faculty Publications 69: Routledge, New York, USA, volume 1(200)3–18.
15. Agnew, C. T.; Anderson, E. *Water Resources in the Arid Realm*. Routledge Physical Environment Series: Routledge, London (1992) 329.
16. Tsakiris, G. ; Loukas, A.; Pangalou, D. ; Vangelis, H. ; Tigkas, D. ; Rossi, G.; Cancelliere, A. Chapter 7. Drought characterization. *Options Méditerranéennes*, CIHEAM/EC MEDA Water, No. 58 (2007) 85-102.
17. Stour, L.; Agoumi, A. Sécheresse climatique au Marocdurant les dernières décennies. *Hydroécologie Appliquée* 16 (2008) 215-232.
18. *Rognon, P. Sécheresse et aridité, leur impact sur la désertification au Maghreb. Sécheresse 4 (1996) 287-297.*
19. Wilhite, D. A.; Glantz, M. H. Understanding the drought phenomenon: The role of definitions. *Water International* 10 (1985) 111-120.
20. White, D.H.; O'Meagher, B. Coping with exceptional droughts in Australia. *Drought Network News* 7 (1995) 13-17.
21. Bergaoui, M.; Alouini, A. caractérisation de la sécheresse météorologique et hydrologique : cas du bassin versant de Siliana en Tunisie. *Secheresse* 4 (2001) 205-213.
22. Bootsma, A.; Boisvert, J.B., De Jong, R. ; Baier, W. Drought and Canadian Agriculture: A Review of the Means of Action. *Drought* 7 (1996) 277-285.
23. Paulo, A. A.; Rosa R. D.; Pereira, L. S. Climate Trends and Behavior of Drought Indices Based on Precipitation and Evapotranspiration in Portugal. *Natural Hazards and Earth System Sciences* 12 (2012) 1481- 1491.
24. Meddi, H.; Meddi, M.Variabilité des précipitations annuelles du Nord-Ouest de l'Algérie20 (2009)57-65.
25. Matari, A.; Kerrouche, M. ; Bousid, H. ; Douguedroit, A.,. Sécheresse dans l'ouest algérien. Publications of the International Association of Climatology 12 (1999) 98-106.
26. Meddi, H. ; Meddi, M., Sécheresse et spatialisation des précipitations dans le nord-ouest de l'Algérie. International Symposium (*Terre et Eau*),Annaba, Algeria, November21- 23 (2004).
27. Medejerab, A. ; Henia, L.Variations spatio-temporelles de la sécheresse climatique en Algérie nord-occidentale.*Courrier du savoir 11(2011) 71-79.*
28. Achite, M. ; Mansour, H. ; Toubal, A. ; Lamrani, C. Etude de la variabilité climatique dans le nord-ouest algérien (Bassin de l'oued Mina) : approche statistique. *International Journal of Environment & Water* 3(2014) 116-122.
29. Ministry of Water Resources (MWR). mission VI : cadastre hydrique du bassin hydrographique du Côtier Algérois, *summary document,* Algiers,Algeria (2003)31.
30. Ministry of Water Resources (MWR).Gestion intégrée des ressources en eau dans le bassin hydrographique côtier Algérois, *Algerian-Belgian cooperation programme No. 0500711*, Algiers, Algeria (2012).
31. Ministry of Equipment and Spatial Planning. Note sur les ressources en eaux souterraines de l'Algérie. Algiers, Algeria,*Summary document*. June 1999.
32. Benlabiod, D.; Medjerab, A. Etude de la sécheresse climatique dans les steppes sud-Oranaises et Algéroises a l'aide de l'indice standardisé de précipitations.*revue agro-écologie* 02 (2014)58-68.
33. Kouassi, A.M.; Kouamé, K.F.; Koffi, Y.B.; Dje, K.B.; Paturel, J.E.; Oulare, S. Analysis of climate variability and of its influences on seasonal rainfall regimes in West Africa: case of the N'zi (Bandama) watershed in Ivory Coast. *Cybergeo : European Journal of Geography, Environnement, Nature, Paysage,* document 513, dec 2010.
34. Dracup, J. A.;Lee, K. S.;Paulson, E. G. On the definition of droughts.*Water Resources Research 16 (1980) 297-302.*
35. Keyantash, J.; Dracup, J. A. The quantification of drought: An evaluation of drought indices.*Bulletin of the American Meteorological Society*83 (2002) 1167–1180.
36. Redmond, K. T.The depiction of drought.*Bulletin of the American Meteorological Society*83 (2002) 1143–1147.
37. Svoboda, M.; LeComte, D., Hayes, M.; Heim, R.; Gleason, K.; Angel, J. R.; Rippey, B. ; Tinker, R. ; Palecki, M. ; Stooksbury, D. ; Miskus, D. ; Stephens, S. The drought monitor. *Bulletin of the American Meteorological Society 83* (2002) 1181-1190.
38. Karavitis, C.; Chortaria, C.; Alexandris, S.; Vasilakou, C.; Tsesmelis, D. Development of the Standardized Precipitation Index for Greece. *Urban Water Journal* 9 (2012) 401-407.
39. Al-Qinna, M. I.; Hammouri, N. A.; Obeidat,M. M.; Ahmed, F. Y.Drought Analysis in Jordan under Current and Future Climates. *Climatic Change* 106 (2011) 421-440.
40. McKee, T.; Doesken, N.; Kleist, J. The relationship of drought frequency and duration to time scales. In: *Preprints of the 8th Conference on Applied Climatology*,1993, Anaheim, California, 179-184.
41. McKee, T. B.; Doeksten, N. J.; Kleist, J. Drought monitoring with multiple time scales. In *Preprints of 9th Conference on Applied Climatology* 1995, 15-20 January. Dallas, TX, 233-236.
42. Moreira, E.E.; Coelho, C.A.; Paulo, A.A.; Pereira, L.S; Mexia, J.T. SPI-based drought category prediction using loglinear models.*Journal of Hydrology*354 (2008)116–130.
43. Hayes, M. J.; Svoboda, M.D.; Wilhite, D.A.; Vanyarkho, O.V. Monitoring the 1996 drought using the standardized precipitation index. *Bulletin of American Meteorological Society* 80 (1999) 429-438.
44. Alamgir, M.; Shahid, S.;Hazarika, M.K.; Nashrrullah, S.; Harun, S.B.; Shamsudin, S. Analysis of Meteorological Drought Pattern During Different Climatic and Cropping Seasons in Bangladesh. *Journal of the American Water Resources Association* 51(2015)794–806.
45. Anctil, F.; Larouche, W.; Viau, A.A.; Parent, L.E. Interpretation of the standardized precipitation indictor using regional statistical analysis. *CJSS*82(2002) 115–125.
46. Guttman, N.B. On the sensitivity of sample L moments to sample size. *Journal of Climatology* 7 (1994) 1026–1029.

47. Vermes, L. How to work out a drought mitigation strategy. An *ICID Guide*, *DVWK Guidelines for water management*, Bonn, Germany, 309 (1998) 29.
48. Agnew, C.T. Using the SPI to identify drought. *Drought Network News*12 (2000) 6-11.
49. Łabędzki, L. Estimation of local drought frequency in central Poland using the standardized precipitation index SPI. *Irrigation and Drainage* 56 (2007) 67-77.
50. Aghrab, A. Caractérisation de la sécheresse et élaboration des indicateurs climatiques pour son alerte précoce dans la région du Sais. Final thesis, National School of Agriculture of Meknes, Morocco (2003) 109.
51. Mohammed Layelmam. Calcul des indicateurs de sécheresse à partir des images NOAA/AVHRR. Research report *in Projet de Mise en place d'un Système d'Alerte précoce à la Sécheresse dans trois pays de la rive Sud de la Méditerranée: Algérie, Maroc, et Tunisie;*IAV, CRTS, CRASTE-LF, (2008)38.
52. OSS.Vers un système d'alerte précoce à la sécheresse au Maghreb- Summary Collection No.4. In *Ecosystèmes terrestres*, Tunis, (2009)84.
53. Jouil, I.; Bitar, K.; Salama,H.; Amraoui, A. ; Moccasit,A.; Tahiri, M. Sécheresse météorologique au bassin hydraulique OUM ER RBIA durant les dernières décennies. *Larhyss Journal* 10 (2013) 109-127.
54. Meddi, M.; Meddi, H. Meteorological and agricultural drought in Northwestern Algeria. In: 2nd Mediterranean Conference on Water and Environment, Algiers, (2002)154–164.



**Please cite this Article as:**

Ladji H., Benrachdi K., Djoumad S., *Analysis of Climatic Drought using Drought Indices in Algiers Region.*,***Algerian J. Env. Sc. Technology**, **5**:***3 (2019) 1062-1071**