EFFECT OF DROUGHT ON WATER RESOURCES IN THE SEMI-ARID REGIONS OF ALGERIA. CASE OF THE BASIN OF THE HIGH PLATEAUS OF CONSTANTINE

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Abstract:

Algeria is one of the most countries likely to be affected by drought, which is typically caused by the effects of climate change. Studies showed that drought periods might become more frequent due to climate change, which threatens wealth, whereas the lack of strategies muddles water and policies to mitigate their negative impacts on water resources. Since Algeria is experiencing increased demand for this critical substance, it is also experiencing scarcity and depletion of its water resources because of a variety of human and natural factors, particularly the drought caused by low rainfall rates. This article aims to show how drought affects water resources in the basin of the high Plateaus of Constantine by using the rainfall measurement index (SPI). The basin is known for being in a semi-arid climate and having natural features like a widening of the drought circle in both space and time, which leads to a decrease in its potential and water resources.

Keywords: Basin of the High Plateaus of Constantine, drought, rainfall index (SPI), precipitation, water resources.

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Introduction

Water is a critical resource for both commercial growth and societal well-being (Novák, 2022). It is the most important factor in the emergence and development of human civilizations (Al-Maliki, 2005), which attracts the population and determines their lifestyle and the type of economic activities (Al-Turki, 2007). The importance of water grew and became one of the most critical issues of the first century (Ghailani, 2012). Its caution is a genuine source of worry for nations, particularly those in arid and semi-arid areas, and has sparked interest in researching it, assessing the natural and human factors influencing it, and planning for its efficient growth and administration (Othman, 2001). Many countries worldwide, primarily Arab and African countries face a significant shortage of water resources (Spash, 2021), which cannot meet the increasing demand from various consuming sectors, particularly agriculture and domestic uses. Many factors contributed to this situation, most notably a decrease in rain and an increase in evaporation, as well as successive years of drought, in addition to population growth and a high level of economic and social development (Bakrkar, 2015).

Drought is regarded as one of the most dangerous natural phenomena to which the planet has been subjected since the twentieth century (Swetalina and Thomas 2016), owing to its invasion of many areas of the globe, resulting in numerous economic, social, and environmental disasters (Novák, 2022). The steep drop in rainfall rates on a daily, monthly, and yearly basis continues to reflect the drought evolution up to the current day (Hlavatá et al., 2018). According to scientific and academic research (Kundzewicz et al., 2006), it is hard to learn more about drought because it is a very complicated natural event (Bougara et al., 2021). Even at the conceptual level, the definition of drought sparked scientific debate and multiple discussions among researchers and specialists, leading to multiple definitions due to the phenomenon's multiplicity of dimensions, including the natural, biological, and human environments (Bazrafshan and Khalili, 2013; Marengo et al., 2011).

Drought is described as a deficit in the overall water budget in a specific region during a specific period due to insufficient precipitation (Bouarfa et al., 2022). It also refers to a shortage of natural water resources in a particular region during a specific period (Fendeková et al., 2017). In other words, precipitation is the major cause of drought because the latter refers to a certain decrease in precipitation and its shift toward a drop with values less than the norm for a group of years (Halmová, 2022). Drought is a natural phenomenon that characterizes North Africa, and its impact on social and economic life has become a reality (Baho, 2002; Maefi, 2020) necessitating research into the causes and consequences of its occurrence to devise mitigation strategies, particularly at the level of water resources.

Algeria represents one of the countries with limited and shrinking water resources because of droughts that have hit the country since the 1970s and the uneven distribution of rain (Bendjema et al., 2019), which decreases from north to south and does not reach the interior and southern areas. Only a tiny quantity of rain fell in these areas (Khezazna et al., 2016). Surrounded by the Tell Atlas Chain Mountains to the north and the Saharan Atlas mountains to the south, Constantine Basin is mostly affected by drought. The two Chain Mountains surrounding it defend it from the effects of moist air masses from the north that bring rain and put it in a semi-arid climate zone.

In this respect, the study issue revolves around the following pivotal question: To what degree did the drought affect the water potential in the basin of Constantine's high plateaus? In turn, this main question raises the following issues: What is the average number of arid years in this basin ? What are the features of its geographic distribution? What are the effects of consecutive years of drought on surface and groundwater resources in the Constantinian High Plateau Basin? This research aims to emphasize climatic drought's occurrence on water resources in the Basin of the High Plateaus of Constantine and to evaluate drought times.

Material and methods

Study area and data

The Basin of Constantine's High Plateaus is situated in northeastern Algeria. It is part of Algeria's High-East Plateaus area, which stretches as a transverse band from southwest to northeast Algeria (Bougarra, 2004). It is limited by the Seybouss basin as well as the Kabeer Al-Rimal Basin to the north (fig. 1), by the Majrada Basin to the east, by the Shatt Al-Malghegh Basin to the south, and by Al-Sumam Basin and the Shatt Al-Houdna Basin to the west. The basin's celestial position is between two longitudes 5° and 7° east and two latitudes 35° and 36° north. The basin of the High Plateaus of Constantine has an area of 9581 km2 with internal drainage, where runoff water discharged into charts and sabkhas situated within the basin, such as Garaet El Tarf, Sebkhat Ezzemoul, and Shatt al-Bayda.

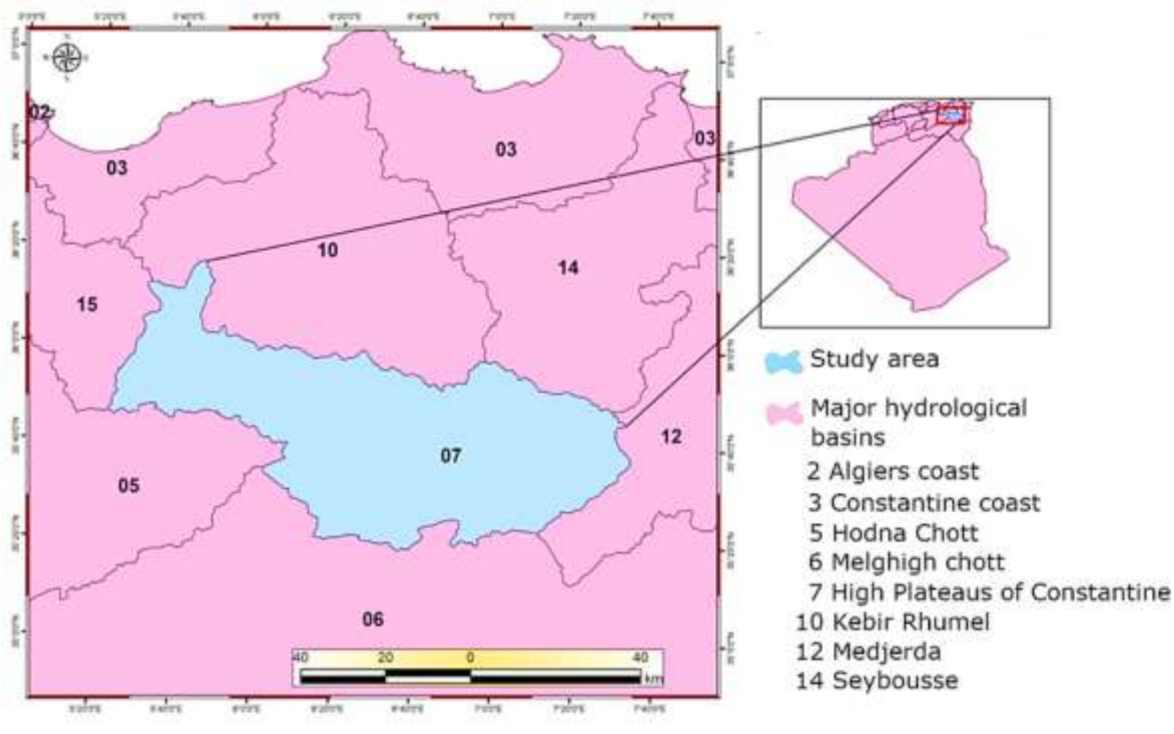


Fig. 1. location of the Basin of the High Plateaus of Constantine.

The Basin of the High Plateaus of Constantine is considered one of Algeria's most important internal basins, as it includes three critical state centers (Batna, Oum El-Bouaghi, and Khenchela), as well as cities of great economic importance and major transit axes (namely El Eulma which is affiliated with the Wilaya of Setif,

and Ain Al-Bayda from the state of Oum El-Bouaghi). It contains 76 towns, 35 of which are completely within the basin. It is located in a semi-arid climate region due to its location between the two chains of the Tell Atlas in the north and the Saharan Atlas in the south. The latter places it in the rain shadow due to the High Atlas Mountains, which acts as a barrier to the arrival of northern humid air masses laden with rain. Its physical separation from the humid effects of the Mediterranean Sea reduced also its precipitation quantities that did not surpass 400 mm/year in most areas.
The basin is distinguished by the variety of its terrain, which includes mountains, plateaus, plains, and hills. However, the plain look, known as the upper plains, where the average height is approximated at 1000 m, gives the region a unique agricultural character, where vast cultivations, particularly cereals, expand. Table 1 shows that Constantine's High Plateaus Basin has seven partial basins with different hydrological features. The most important is the Wad al-Shamra basin, where water flows from Wadi Raba and Wad al-Shamra. In terms of density, which refers to the connection between the total lengths of the valleys in the basin and its area, Constantine's High Plateaus Basin has a low drainage density estimated at 0.65.

Table 1. Partial basins of the Constantinian Highlands Basin

Code	0701	0702	0703	0704	0705	0706	0707
Partial basin	Chott beida	Merdja zana	Sebkhet ez-zemoul	Oued chemora	Garaet annk djamel	Oued boulfreiss	Gareat et tarf
Surface (km2)	1596	1036	1560	764	1232	960	2430

Rainfall data and precipitation characteristics

A collection of rain stations is spread differently across the basin's geographical region (fig.2). However, many of them cannot be relied on in the research due to a lengthy period of no available data or numerous interruptions in their data. As a result, in this study, we relied on 10 stations that respond to some scientific characteristics, particularly the station's location, spatial distribution within the basin, and the availability of data for more than 30 years for most stations, which is a sufficient period for an accurate climate study. Table 2 shows the statistical features of the yearly climate data collected at the study sites in Constantine's high plateaus from 25 to 52 years.

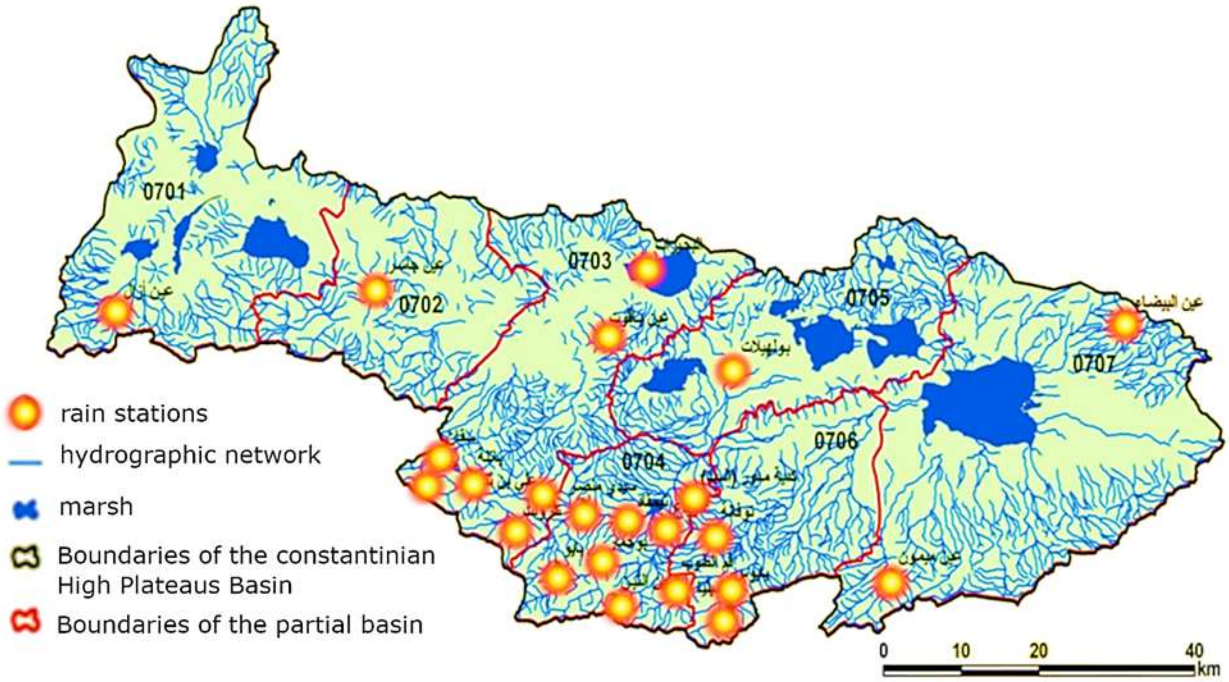


Fig. 2. Distribution of rain stations in the basin of the high plateaus of Constantine.

Table 2. Stations approved in the study

Station	Period	number of years	x	y	z	annual rate	precipitation min	precipitation max
Oum El Bouaghi	1984 - 2012	29	910.1	260	891	368.9	184.7	635.4
Batna	1977 - 2012	36	814.70	257.35	1040.0	327.14	189.5	501.5
Timgad	1969 - 2014	46	841.75	250.90	1000.0	284.23	61.5	491.8
Sidi Mancer	1969 - 2012	44	833.70	253.25	1112.0	328.6	153.6	550.2
Ain Beida	1988 - 2012	25	924.15	288.00	1004.0	420.0	218.2	676.4
Ain Mimoune	1968 -	42	886.35	243.60	1180.0	439	139.9	704.4

	2010							
Foum El Guiss(Bge)	1971 - 2009	36	884.50	250.15	945.0	329.59	129.7	752
Bayou	1969 - 2012	44	829.65	242.65	1510.0	370.19	187.2	615.2
Yabous	1968 - 2020	52	858.45	239.65	1200.0	445.29	138.8	991.1
Chelia	1969 - 2012	51	858.85	237.10	1260.0	521.25	252.7	771.2

Because of its geography, topography, and distance from the Mediterranean Sea, the Basin of the High Plateaus of Constantine has a semi-arid climate beside the Atlas Mountains, which blocks the passage of moist air masses from the north. Figures 3 and 4 demonstrate that the rainfall is irregular on an annual and monthly basis, as well as a dearth of precipitation in the basin compared to the northern basins because precipitation rates in Algeria decline from north to south (Mohsen, 2013). The wet season lasts from October to April within the region. The rain falls considerably less frequently during the dry season, from June to September. July and August have the lowest monthly rainfall totals, with less than 10 millimetres.

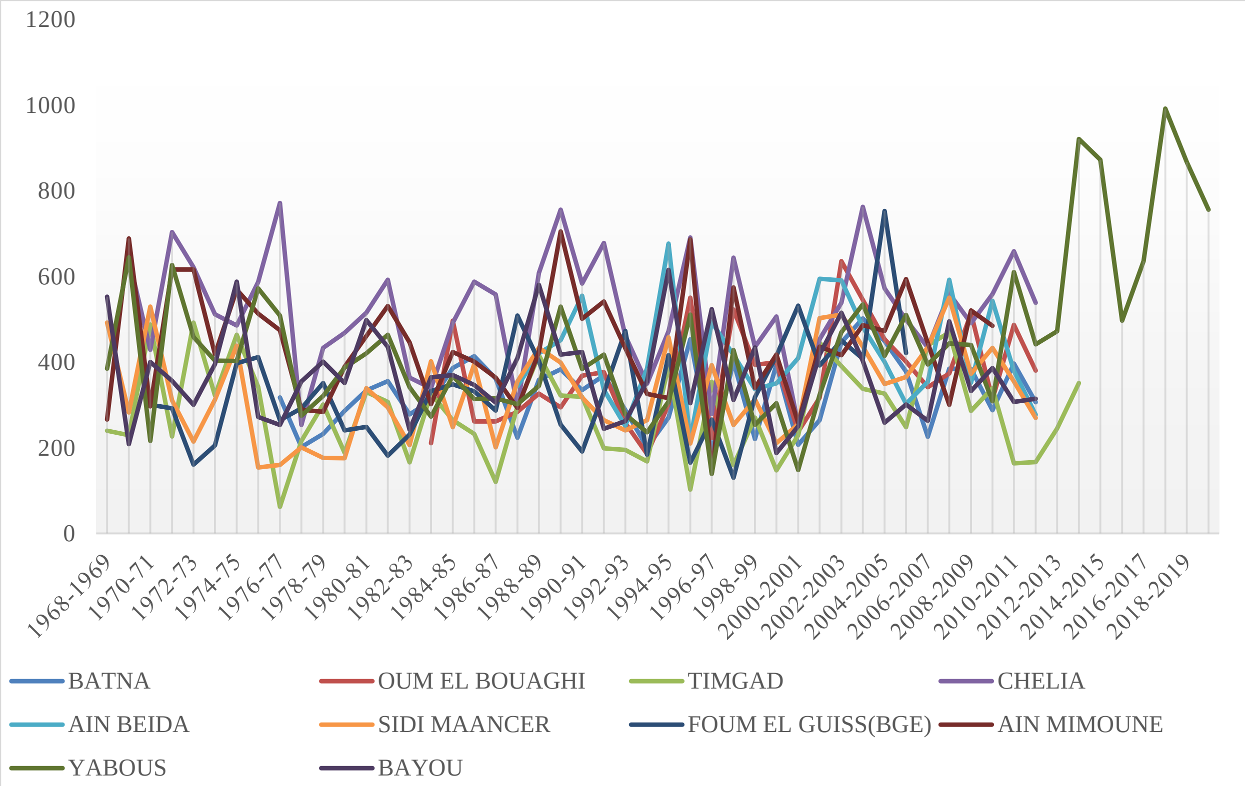


Fig. 3. Distribution of annual rainfall in the basin of the high plateaus of Constantine.

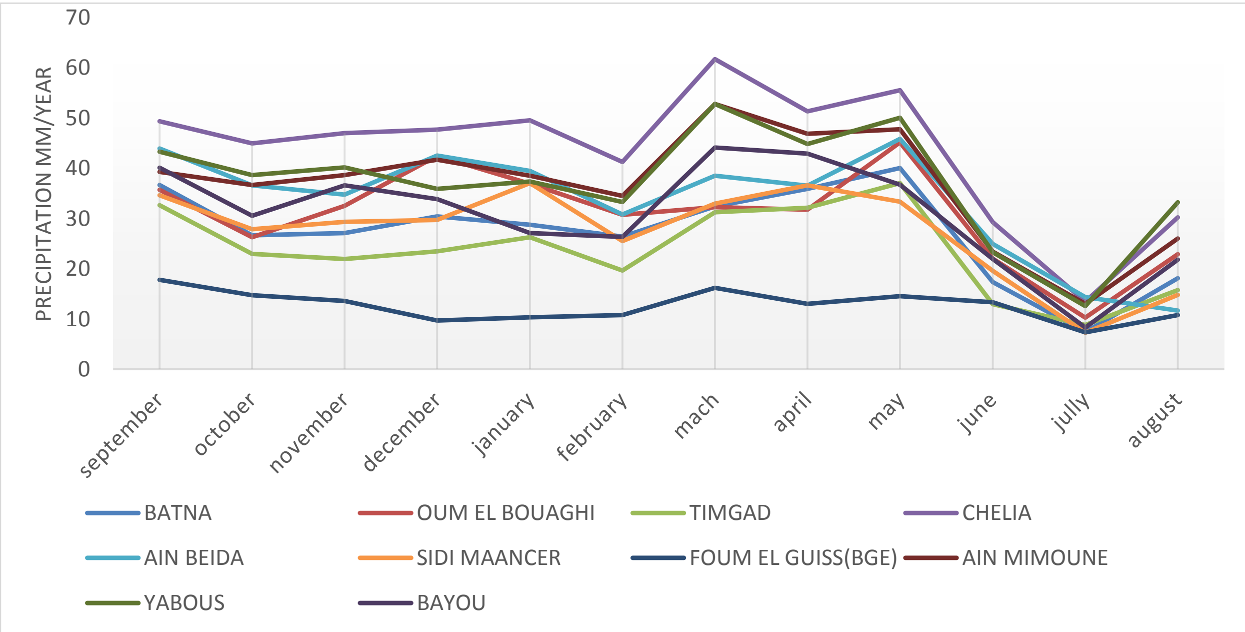


Fig. 1. Monthly changes in precipitation in the Basin of the High Plateaus of Constantine.

The region occasionally gets concentrated thunderstorms and showers that surpass tens of millimetres, with the Shelia site receiving 60 mm per year. This sort of precipitation is a notable characteristic of Algeria's climate in general. The flood of Oued Rabaa on September 1, 1989, with a flow of 297.5 m3/s, the flood of Wadi Fom al-Guiss on May 28, 1991, with a flow of 1076 m3/s, and the flood of Wadi al-Shamra on May 28, 1989, with a flow of 190.7 m3/s, were all produced by this rainfall. Furthermore, the average number of wet days within the basin varies between 40 and 60 rainy days in modest amounts (NAWR, 2021a), as the Kadiyat al-Madwar dam station recorded a daily precipitation rate of 69 days (NAWR, 2021b), and Ain Yaqout and Ain Jasir stations situated in the basin's middle recorded a daily precipitation rate of 69 days (Halimi, 1968). Only 33 and 42 wet days were recorded in Constantine's upper plateau. Fig. 3 shows that annual rainfall amounts in the basin of the upper Plateaus of Constantine are irregular, rising one year and decreasing the next or for successive years. For example, the Yabous station, located in the south of the basin, recorded 991 mm in the 2017-2018 season and 920 mm in the 2013-2014 season, and previously, from 1969 to 2014, the amount of precipitation did not exceed the threshold of 610 mm. Between February and May, the rains are centered in the higher Plateaus of the Constantine region. Summer rains diminish, particularly in July and August, as temperatures increase significantly. The Foum Al-Guiss station is the basin's minor rainy station, as the monthly quantity of precipitation does not surpass the 20-millimetre benchmark. Rainfall in Algeria is distinguished by its fall in the winter and lack in the summer. However, it is known to vary more in the region of the high plateaus of Constantine, and rains occur in the spring season, particularly in March and April.

The average precipitation amounts for the examined times have decreased. Over 46 years, it was within the threshold of 284.23 millimetres at the Timgad station. The average rainfall at Batna station was determined to be 327.14 millimetres over 36 years. The average rainfall at the Yabous station in the southern portion of the basin was calculated to be 445.29 millimetres over 52 years from 1969 to 2020. Since the summit of Chelia is the highest mountain in the northern portion of Algeria, it is feasible to exclude the Shelia station, where the average period between 1969 and 2012 was calculated at 521 25 mm. In terms of rain, most of it falls in the southern part of the basin, near the northern slopes of the Shelia Mountains, Mount Eshmol, Mount Ishali, and Mount Bolrouah, where stations in the basin's southern part recorded the most rain (The average amount of precipitation at Ain Mimoun station was 439 mm). This high average could be explained by the physical position on the northern side of the Aures Mountains, which gets northern moist air currents and converts them into terrain rainfall, the quantity of which can surpass the 1000 mm mark in the Aures Mountains' summits.

These relatively high amounts of rain have formed many large-flowing valleys, like Wadi Raba'a, which empties into the Kadiyat El Medawar Dam, and Wadi Al Shamra, which drains an area of 280.5 km2 in addition to Wadi Bolfrais. The northern and centre rivers flow through temporary valleys. It has a low output and is almost ranked first. The weakness of the rains in the region of the higher Plateaus of Constantine can be explained by the feature that characterizes the rains in Algeria, as the winds responsible for the rainfall are the northwest winds that meet with the hilly Atlas mountains. As a result, they ascend, condensation happens, and rain falls, but they only reach this area once it has nearly emptied (Taibi, 2011). Studies done by the National Agency for Water Resources (NAWR) have shown that the amount of rain in Algeria has decreased by between 10 and 20% since the 1960s, supported by the results of the SPI index. The amount of rain that has fallen in the Basin of the High Plateaus of Constantine in recent years has been irregular and followed by years of drought.

Methods

By employing the Standardized Precipitation Index (SPI), this study attempts to identify the wet years and the dry years, then analyze the dry years and classify their degree of intensity, frequency, spatial distribution, and the extent of their impact on the water capabilities of the Basin of the High Plateaus of Constantine. Dry and rainy years are then compared to calculate the frequency of rain deficit times in the region. This indicator was chosen for its long-term reliance on precipitation data, as opposed to some other indicators that rely on both precipitation and temperature data, such as the drought coefficient, Gossen coefficient, and others, and for its ease of use, as calculating this indicator requires the availability of annual and monthly climatic data stations, from which rain deficit percentages can be calculated. The World Climate Organization has also accepted this indicator, which has been used as one of the most significant scientific markers for investigating the occurrence of drought in many areas around the globe. We use the following equation to compute this indicator:

$$spi=((X_i\bar{A}))/S \qquad (1)$$

where
X_i –the total rainfall during a year (i),
$\bar{A}$ –the average annual precipitation during the studied period,
S –the standard deviation of precipitation during the studied period.

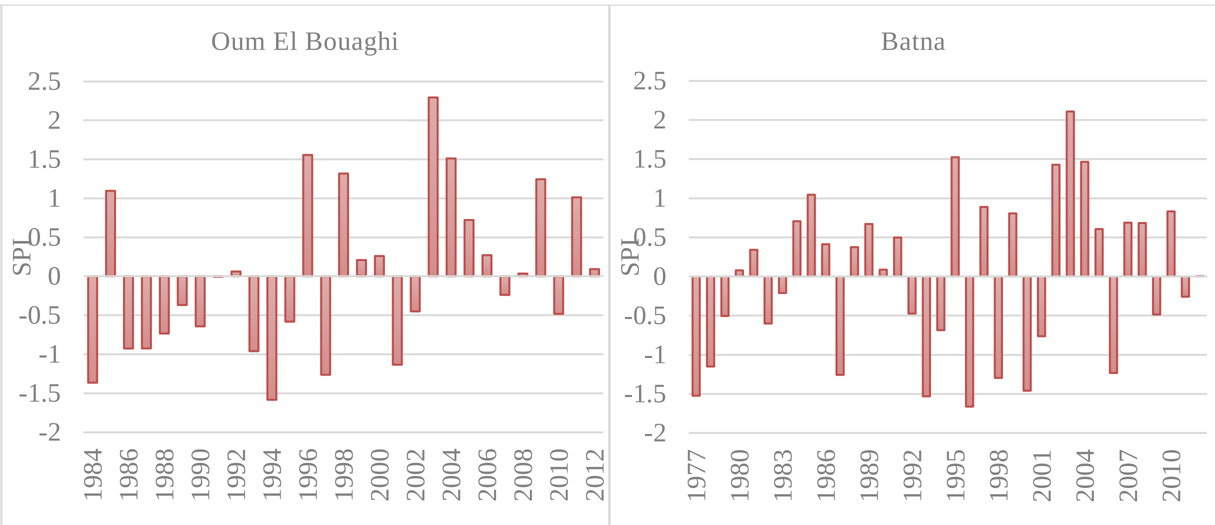
The Standard Rain Index (SPI) is split into seven groups or classes varying from high humidity to very severe drought (Table 3), with negative values representing drought and a deficiency in yearly precipitation compared to the examined period's normal. Positive values, on the other hand, indicate instances of drought. Humidity indicates that rainfall quantities exceeded the study period's normal.

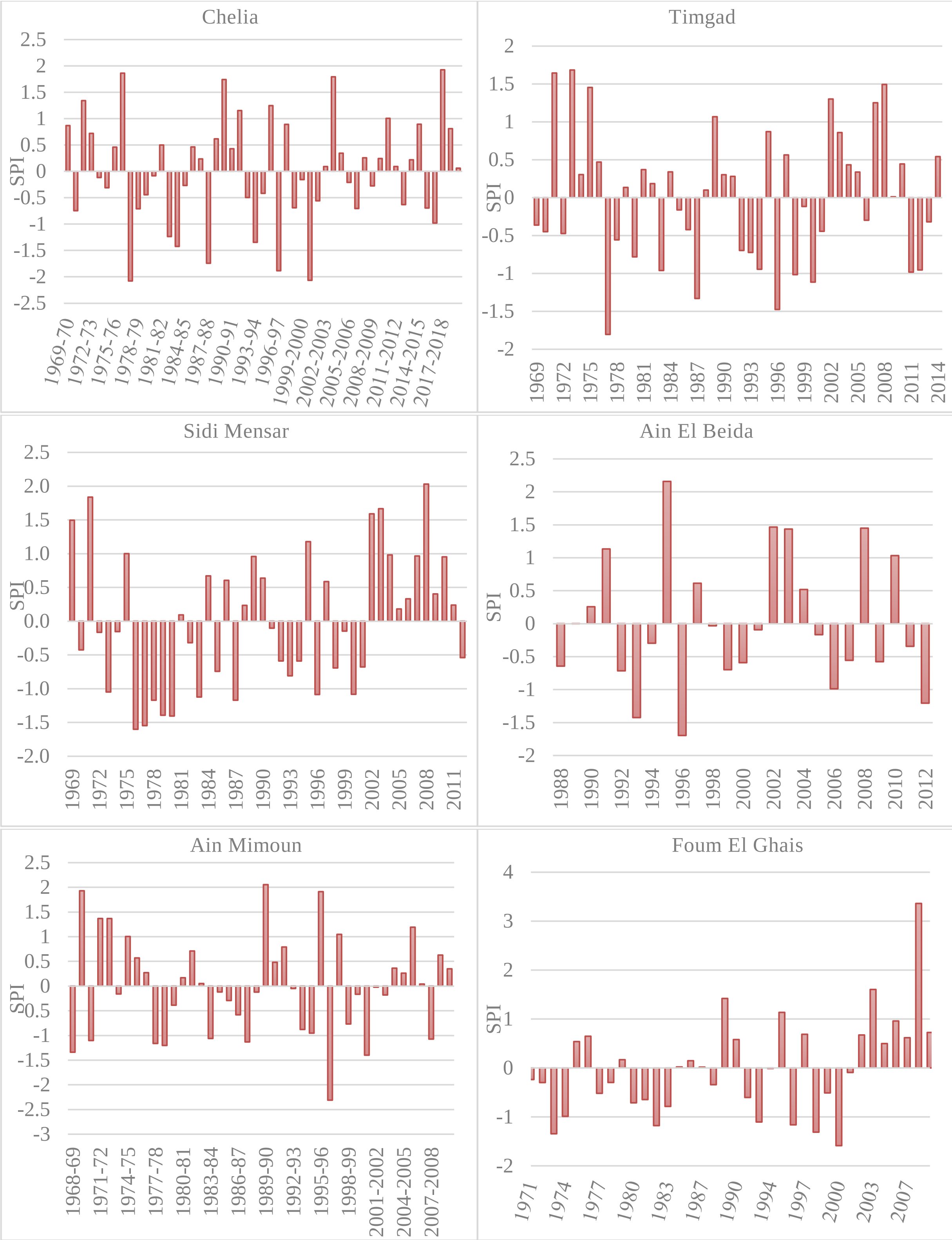
Table 3. SPI Values

SPI	≥ 2	1.99 to 1.5	1.49 to1	0.9 to -0.99	-1.49 to -1	-1.99 to -1.5	≤ -2
Drought degree	extremely wet	very wet	moderately wet	near normal	moderately dry	severely dry	extremely dry

Results and discussion

Based on the results of calculating the standard rain index in the stations of the High Plateau Basin of Constantine (fig. 5), drought cases are common, especially in the basin's southern and central stations, where they are estimated to be 64% in Ain Al-Bayda, 52.3% in Ain Mimoun, 61.5% in Yabous, and 54.5% in Bayeux. Wet years with more rain than the yearly norm had 24% of it in Ain Al-Bayda, 47.6% in Ain Mimoun, 38.4% in Yabous, and 45.4% in Bayeux (fig. 6). These are low numbers when compared to dry years. The SPI index results also show a phenomenon of successive years of drought, which occurred between 1992 and 1994 and was repeated in 2005–2007 in Ain Al-Bayda station, in Ain Mimoun station between 1978 and 1980, and another drought period that lasted for 6 years between 1984 and 1989 in Yabous station. The era of consecutive years of drought was important, lasting from 1978 to 1995, an estimated 18 years. The Bayou Station was also noted for three consecutive years of drought between 1976 and 1978, a stretch of five consecutive years between 1983 and 1987 and 1992 and 1994, and others between 2005 and 2007.




Chelia
SPI
1969-70 1972-73 1975-76 1978-79 1981-82 1984-85 1987-88 1990-91 1993-94 1996-97 1999-2000 2002-2003 2005-2006 2008-2009 2011-2012 2014-2015 2017-2018
Timgad
SPI
1969 1972 1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014
Sidi Mensar
SPI
1969 1972 1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011
Ain El Beida
SPI
1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Ain Mimoun
SPI
1968-69 1971-72 1974-75 1977-78 1980-81 1983-84 1986-87 1989-90 1992-93 1995-96 1998-99 2001-2002 2004-2005 2007-2008
Foum El Ghais
SPI
1971 1974 1977 1980 1983 1987 1990 1994 1997 2000 2003 2007

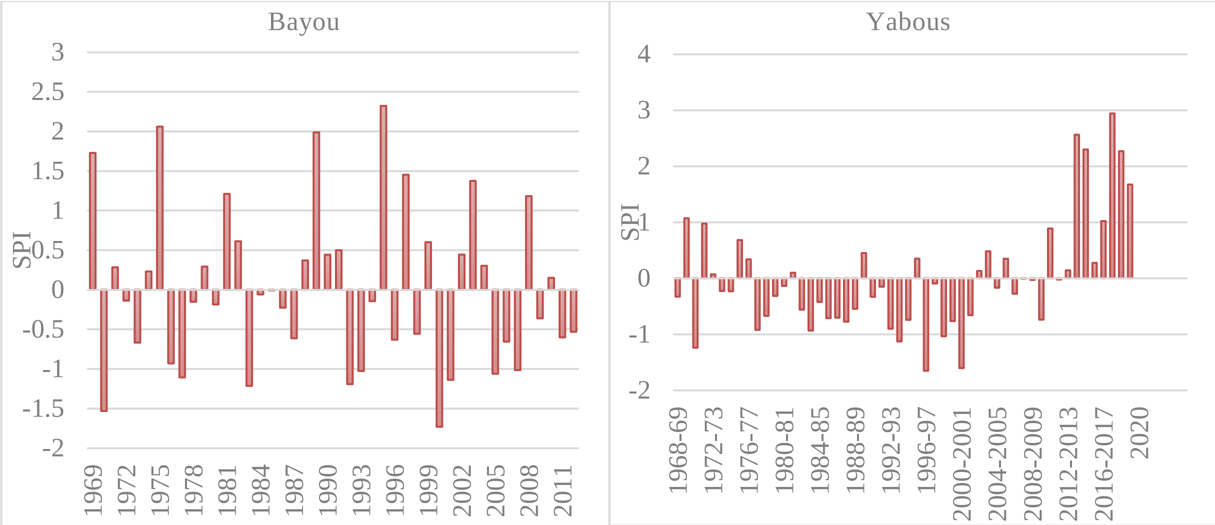


Fig. 5. SPI values in the stations of the High Plateau Basin of Constantine.

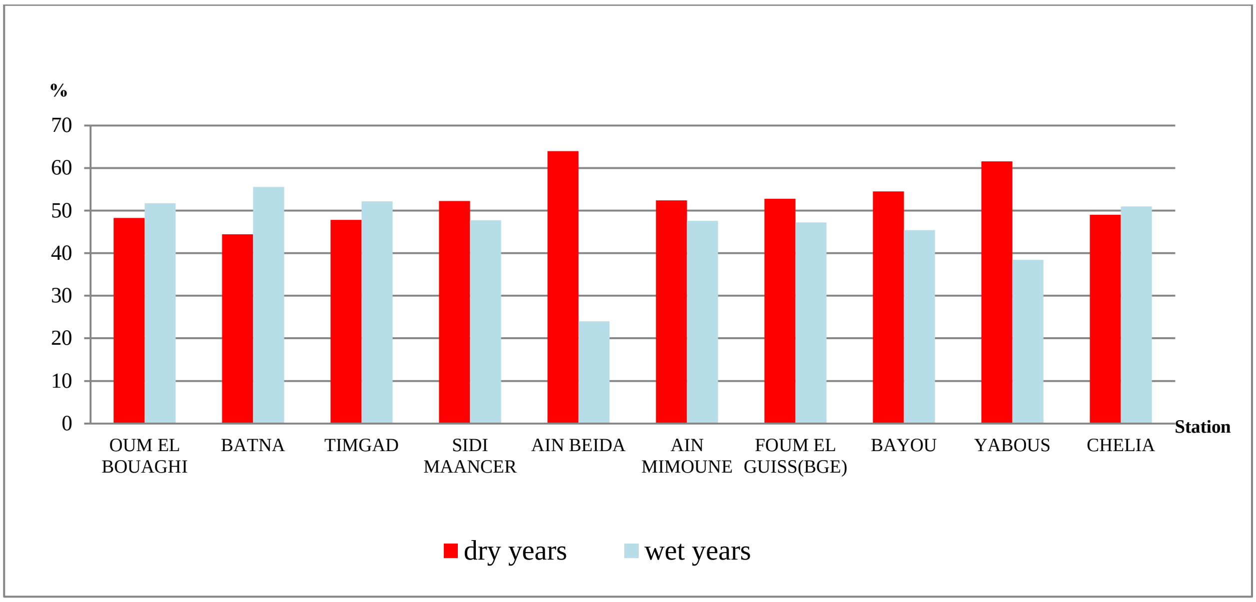


Fig. 6. The ratio of dry and wet years for the study stations, according to the SPI index.

The indicator shows how drought is controlled in the basin. It is estimated that 83.7% of the drought went from an indicator less than average (near normal) to extreme dryness (extremely dry). This high number hurts the basin's surface water sources because rainwater is the main thing that controls these sources. Wet years are expected to be only 16.3% of the time, ranging from moderately to extremely wet, as very wet years were reported in Bayo station in 1975 and 1995 and four years in Yabous station in 1914, 2015, 2018, and 2019 (Table. 4). When we analyze the changes in rainfall from 1980 to 2010, we can see that the Constantine basin has had many droughts since the 1990s. The average rainfall at the Ain Mimoun location between 2000 and 2010 was calculated to be 438.61 mm, while it was 452.34 mm between 1990 and 2000. In the Batna area, the average rainfall fell between 1990 and 2000 compared to 1980–1990, measured at 318.25 mm and 335.01 mm, respectively. The same is true for Yabous station, where the average for 1990–2000 was estimated to be 343.96 mm, compared to 368.34 mm for the prior decade from 1980–1990.

Table 4. The number of years corresponding to the SPI value

Spi	≥ 2	1.99 to 1.5	1.49 to1	0.9 to -0.99	-1.49 to -1	-1.99 to -1.5	≤ -2	Total
Drought	Extremely wet	Very wet	Moderately wet	Near normal	Moderateley dry	Severly dry	Extremely dry	
Oum el bouaghi	1	2	4	18	3	1	0	29
Batna	1	1	3	23	5	3	0	36
Timgad	0	1	5	35	4	1	0	46
Sidi maancer	1	3	3	26	9	2	0	44
Ain beida	1	0	5	16	2	1	0	25
Ain mimoune	1	2	5	25	8	0	1	42
Foum el guiss(bge)	1	1	2	26	5	1	0	36
Bayou	2	2	4	27	7	2	0	44
Yabous	4	1	2	40	3	2	0	52
Chalia	0	4	4	36	3	2	2	51
Total	12	17	37	272	49	15	3	405

Based on the SPI, the Basin of the High Plateaus of Constantine has a high drought rate, especially during the 1980s and 1990s when the standard rain index (SPI) was between -1.3 and -1.4, meaning there were a lot of severe droughts. Examples of drought include places in the middle of a valley, which makes drought a physical fact, and droughts that last for several years and lead to hydrological and pedological drought. Because of the climate, the Constantine Basin often runs out of water, and the amount of water stored in dams, especially the Kediet El Medawar dam and other earthen dams, changes. The various valleys during their flow or through irrigation facilities, such as the dam of Kediat El Medawar, with a capacity of 62 hm3, directed to drinking for both Batna and Ares and the dam of Foum El Guiss, with an estimated capacity of 3.4 hm3, designated for irrigation of the Rumaila plain in the Wilaya of Khenchela, despite its high muddiness. In addition to the earthen dams, whose volume is believed to be 0.58 hm3,

According to the National Water Plan, the groundwater supplies in the Basin of the High Plateaus of Constantine are expected to be 121.70 km3 per year. It is deployed and utilized by 279 forages: 65.94% for the drinking sector, 4.30% for industry, and 29% (64% for irrigation). Groundwater is exposed to intensive use and tremendous strain because it is the basin's main water supply compared to the other sources, which resulted in a significant decrease in its levels, an increase in the profundity of intrusions, and the desiccation of many of them. As a consequence of the drought, the Kediet El Medawar dam experienced a scarcity of bottled water quantities varying from 1.14 to 5.26 hm3 between 2005 and 2019, and the dam's fill rate is continuously decreasing. It is only at 60% of its maximum capability. The second is the Foum Al-Guiss Dam, which is noted for its high mudflow rate and has reduced its water capacity (Irrigation Directorate of Khenchela, 2021).

Since the 1980s, there has not been enough rain in the Basin of the High Plateaus of Constantine, leading to a decrease in underground water resources. This situation is because the aquifers have been put under much pressure by excessive and irrational exploitation, which has caused their levels to drop, causing a drought. There are numerous shafts and wells inside the basin, and the depth of the shafts is expected to rise by 150 meters on average. Without groundwater recharge options, there is a risk of endangering these sources and depleting their reserves. This situation has resulted in a significant decrease in the per capita share of water and fluctuations in water distribution, particularly during the summer, when the demand for this vital substance increases. Water is distributed to the population at a rate of 1/3 of a day, and many areas are supplied through tanks (Irrigation Directorate of Batna, 2021). Many projects and farming activities in the area, which has good agricultural capabilities, have been hampered by water and the decrease in water potential in the watershed.

Conclusion

The successive periods of drought and low rainfall contributed to a significant decline in the basin's water potential, given that rain is the most important source of water resources and directly impacts ground and surface water. As the basin recorded a high frequency of droughts during various periods since the 1980s, this manifested in a significant decrease in precipitation quantities, in addition to the issue of consecutive dry years, with estimates ranging from 3 to more than 6 consecutive dry years. This situation has significantly contributed to the shrinking of the mobilized, mobilized water potential within the basin's dams as well as a decline in the level of aquifers as a result of intensive and irrational use, in addition to increased demand for this vital material, particularly in the drinking and water sectors.

Given this situation and the basin's water problem worsening, significant diversions from the north to the plateau region were relied on as an alternative solution. The most significant is the transfer of the Bani Haroun Dam's waters to the wilayat of Oum El-Bouaghi via the Orkis Dam and to the wilayat of Batna via the Kediat El Medawar Dam, in addition to the dam's diversions. Oued El Sherif in the wilaya of Souk Ahras supplies drinking water to some of the basin's most important towns, particularly Ain El Beida. In this case, we need to reduce how much water we use and find ways to deal with how often droughts happen. The basin's combined management of water resources has become critical, particularly given that the Basin of the High Plateaus of Constantine is a unique physical region with a population of more than 1.5 million people. It is currently accessible. It has significant economic potential, particularly in the agricultural sector, as it is one of the most critical areas in Algeria for cereal production, which is regarded as one of Algeria's key commodities for achieving food security.

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