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EVALUATION OF CLIMATIC CONDITIONS FROM 1978 TO 2020 OF OUED SOUF VALLEY (SOUTHERN EAST OF ALGERIA)

AYOUB BARKAT*[1], FOUED BOUAICHA[2], ZAKARIA RAHAL[3], TAMÁS MESTER[1], GYÖRGY SZABÓ[1]

[1] Department of Landscape Protection and Environmental Geography, University of Debrecen, 4032 Debrecen, Hungary
[2] Laboratory of Geology and Environment (LGE), Université Frères Mentouri Constantine, Constantine 25020, Algeria
[3] Department of Water Supply and Sanitation, Don State Technical University, 344000 Rostov-on-Don, Russia
*Email: ayoub.barkat@science.unideb.hu

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Abstract

In this research, a climatic synthesis was built to assess the climatic parameters of the Oued Souf Valley through the meteorological data obtained from Guemar station (airport). It was revealed that the hydrological year of Oued Souf Valley is branded by the presence of a dry period and the total absence of a wet period over the year, even during January, when it was observed to have the lowest temperature and highest precipitation, which classified it as a Saharan climate (Hyper arid). The irregularity and the scarcity of precipitation, high temperatures and extremely high evapotranspiration had significant repercussions on surface runoff and infiltration which implies a high pressure on the water resources of Oued Souf valley and may disrupt the future socioeconomic project and increase the damage of natural drought and desertification.

Keywords: climatic synthesis, drought, water budget

1. Introduction

Global warming is one of the most pressing issues that must be addressed since it is critical to comprehending the global water cycle. However, numerous studies have been carried out to better understand water cycle variables such as temperature, evaporation, infiltration, and rainfall, which is a major source of the water cycle (Meddi et al., 2010; Duncan et al., 2013; Pathak et al., 2017; Santos et al., 2018; Zerouali et al., 2020; Dang et al., 2021; Zerouali et al., 2022; Zerouali et al., 2022).However, the analysis and characterization of hydroclimatic variability over a long period prove to be fundamental for understanding the impacts of climate change and the vulnerability of hydrological regimes (Baudet et al, 2017). However, the results of the climatic variability resulted in the occurrence of a natural phenomenon called “drought” which may occur in any climate and any part of the world.

Drought has been defined through different academic expertise reliant on the specific area of research interests, as a natural hazard phenomenon that can be resulted from an abnormally low amount of water at the land-atmosphere interface due to the considerable scarcity of precipitation (meteorological drought) which influences all aspects of the water cycle and can spread to soil moisture (agricultural drought), stream flow, lake levels, and groundwater as it persists (hydrological drought)(Wilhite, 2000; Balla et al., 2016; Berg et al., 2018). However, different definitions have been developed to classify systems that define drought. For example, Dracup (1980) stated that drought is classified by four criteria: the nature of the water deficit, averaging period, truncation level and method of regionalization. Wilhite et al (1985), have categorized drought into six categories: meteorological, climatological, atmospheric, agricultural, hydrologic and water management. Another definition can be mentioned that Drought is a lack of rainfall so great and long-continued as to damage the plant and animal life of a place and to deplete water supplies both for domestic purposes and for the operation of power plants, especially in those regions where rainfall is normally sufficient for such purposes according to the US Weather Bureau (Keetchet al, 1968). Meanwhile, a drought period is a period of time, usually measured in months or years, during which the actual moisture supply at a specific location consistently falls short of the climatically predicted or climatically appropriate moisture supply (Khalili et al, 2011).

Anyway, Algerian Sahara is one of the biggest in the world where the climatic conditions reach their amplitude which increases the probability of drought occurrence and threatens its environment and even the socioeconomic project of the Oued Souf habitat as a part of it. For that reason, and for the first time, this research paper aims to contribute to climatic synthesis realization using a combination several climatic indicies such as (musset index, emberger index, bagnouls and gaussen index and De martonne index) (Castri, 1973; Mesfek et al, 2021; Nesrine et al, 2022; Kirk, 1974; Lungu et al, 2011; Haider et al, 2014; Joshi, 1982; Gentilli, 1989) and consequently water budget as a primary objective over a period of 42 years from 1978 to 2020 to highlight the local climate drought for the first time in Oued Souf valley.

2. Materials and methods

Study area description and data collection

The study area is Oued Souf Valley, which is located in the North-eastern part of Algeria. It is known by its high agricultural production nationally such as potatoes, tomatoes, dates, etc. On the other hand, Oued Souf Valley represents a very presses national heritage because of its traditional environment. Climate data for the period 1978 to 2020 were obtained from the meteorological station of El Oued - Guemar airport. These data include: mean monthly rainfall, maximum monthly temperature and minimum monthly temperature. The meteorological station is located in the coordinates Longitude 06°47’E and Latitude: 33°30’ N with an altitude of 63 m as it is shown in Fig 1.

Climatic synthesis

One of the main goals of this project is to create a climatic synthesis, which entails characterizing the variation in temperature and precipitation in the area and generating the following indices: The Emberger index, the Bagnouls and Gaussen aridity index, and the De Martonne index are all used to calculate seasonal rainfall patterns. The bioclimate characterization was performed using different aspects. Musset developed the seasonal rainfall regime in 1935 Musset (1935); Bensmira et al (2015) by computing the seasonal relative coefficient:

$$C_{rs} = P_s \times \left(\frac{4}{P_a}\right) \qquad (1)$$

where Ps indicates seasonal precipitation (mm) and Pa represents annual precipitation (mm). It involves classifying each season based on the quantity of average annual precipitation recorded during that season,

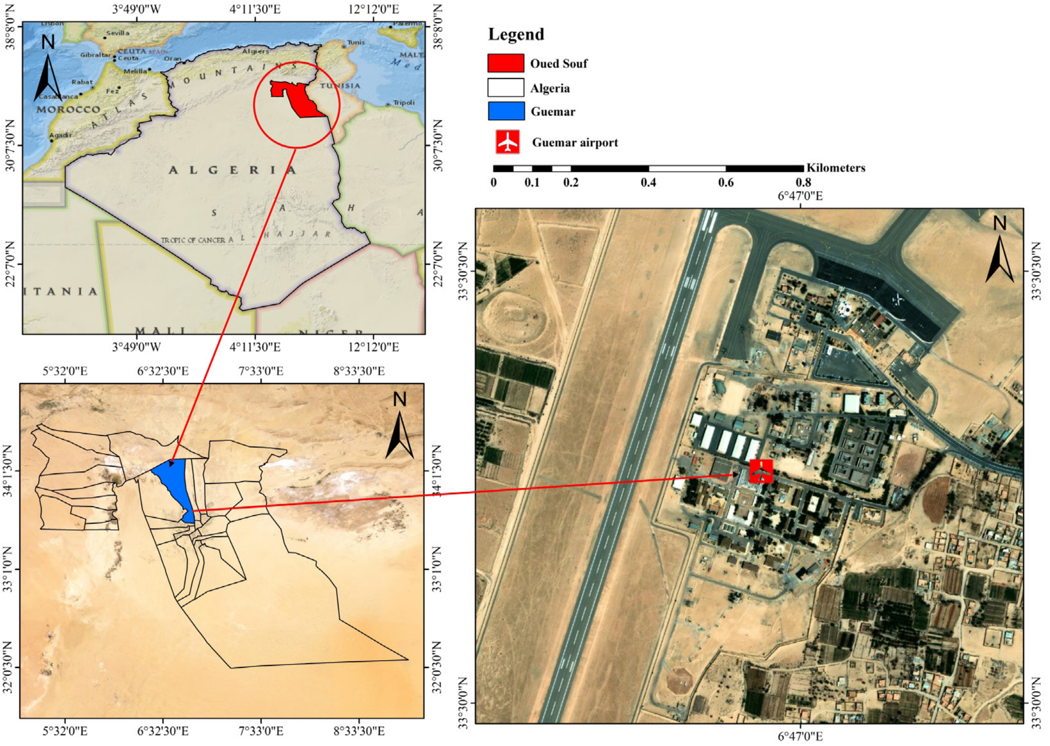

Fig. 1. Study area map and meteorological station location

as indicated by its initial value (Sp: spring, Su: summer, Au: autumn, Wi: winter). The classification is done in decreasing the order of rainfall. The lower the Crs coefficient, the greater precipitation deficits characterize the season.

Emberger developed the Q2 quotient in 1955 Emberger (1955), which is defined as follows:

$$Q_2 = \left(\frac{2000 \times P}{M^2 - m^2}\right) \qquad (2)$$

Whereas P is the average annual rainfall (mm), M is the average of the hottest month's maximum (°C), and m is the average of the coldest month's minimum (°C). The Emberger climagram will be used to identify the new bioclimatic location of the study area using the quotient Q2 and the value of m (1978-2020).

Bagnouls and Gaussen's aridity index corresponds to the ombrothermic index, which reflects the duration and intensity of the dry season and reflects the effect of water stress on the growth of vegetation and biomass formation Bagnouls & Gaussen, (1953). It is used in the Mediterranean region to identify drought-related events and to assess regions vulnerable to desertification Kosmas et al (2006). A month is dry for Bagnouls and Gaussen if the total precipitation expressed in millimeters is equal to or less than double the average temperature T expressed in degrees centigrade for the same month:

$$P \leq 2T \qquad (3)$$

De Martonne's index is an annual aridity index De Martonne (1926); Challi et al (2021) that is defined as follows:

$$I = \frac{P}{T+10} \qquad (4)$$

T = Annual Mean Temperature (°C) and P = Annual Mean Precipitation (mm). When the index value falls, aridity rises. De

Martonne proposed six major macroclimate classifications at the global level, ranging from desert or hyperarid zones (I< 5) to humid zones with predominantly forest (I> 40). Extreme rainfall is a characteristic of hyper-arid regions. The following are the values of this index when expressed in broad macroclimate classes: Hyper-arid (<5), arid (5-10), semi-arid (10-20), subhumid (20-30), humid (30-40), and hyper humid (>40) are the different types of aridity.

Water budget quantification

The establishment of the water balance of a given region consists in evaluating the distribution of precipitation received on a surface, between the different components, namely flow, infiltration and evapotranspiration, for the purpose of establishing an equation of balance between contributions and losses which directly influence the variation of reserves. The water balance equation is expressed by the relationship:

$$P = RET + R + I \qquad (5)$$

With: P: average annual precipitation in (mm), R: runoff in (mm), I: average infiltration in (mm), RET: reel evapotranspiration. At the same time, was necessary to determine the real evapotranspiration using the Turc approach Turc (1955), and the potential evapotranspiration using DrinC software based on the Thornthwaite approach Thornthwaite (1948). While the Tixeront-Berkaloff formula was used to calculate the runoff.

3. Results and Discussion

Climatic parameters analysis

The origin of precipitation in the Saharan regions is different according to the seasons. During the summer they are due to monsoon depressions, in winter they are due to depressions accompanying the southward migration of the polar fronts. During the intermediate period, these precipitations are due to the Sudano-Saharan depressions crossing the Sahara from the south to the north Dubief (1963). However, the rainfall in Oued Souf region is typified by low, oscillatory, and infrequent precipitation (Barkat et al, 2020; Barkat et al, 2021). Fig 2,

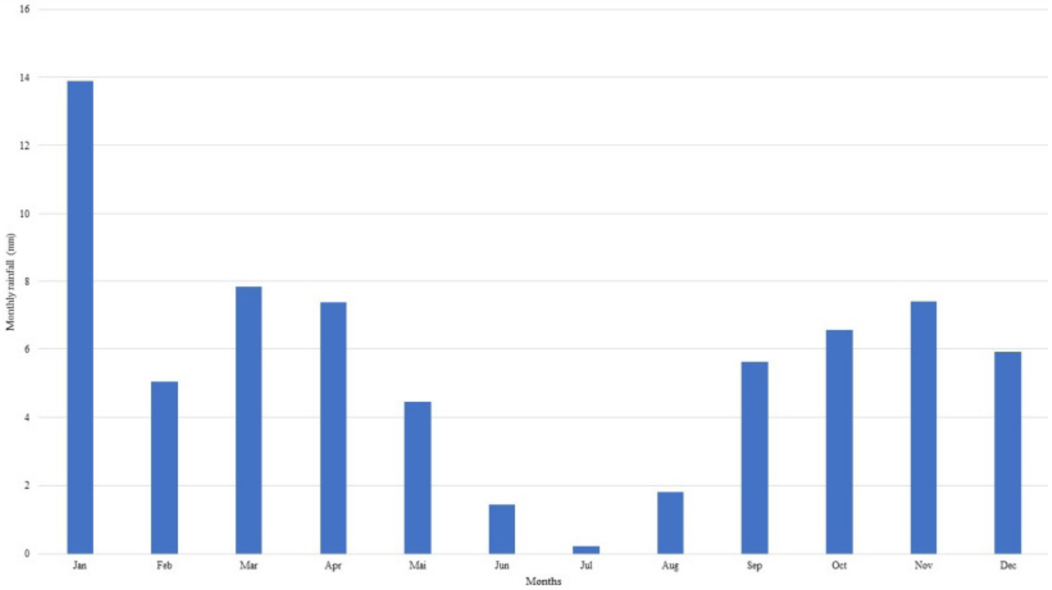

Fig 2. Histogram of average monthly precipitation over 42 years (1978-2020).

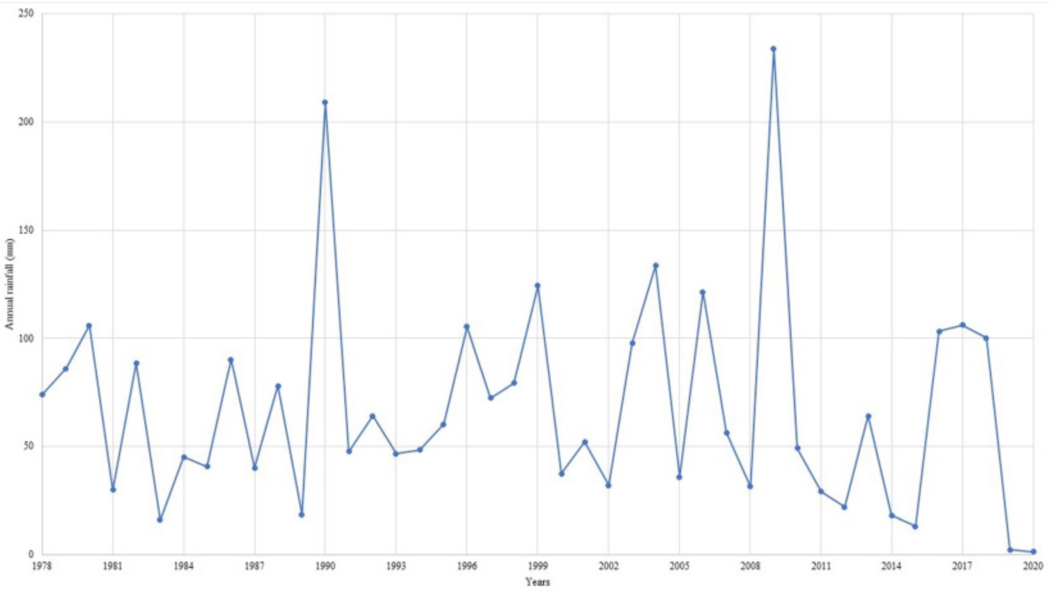

Fig. 3. Distribution of annual precipitation between (1978-2020)

illustrates the monthly average precipitation within an observation period of 42 years (1978-2020). The variability of rainfall over time in the studied period is very clear in this graph, hence the monthly maximum rainfall is around 13.89 mm observed during the month of January, while the monthly minimum is around 0.23 mm detected during the month of July. Moreover, the total annual average precipitation over 42 years is 67.63 mm.

Based on Fig 3, which shows the annual distribution of rainfall, the rainiest year was 2009 with 233.7 mm, while the driest was

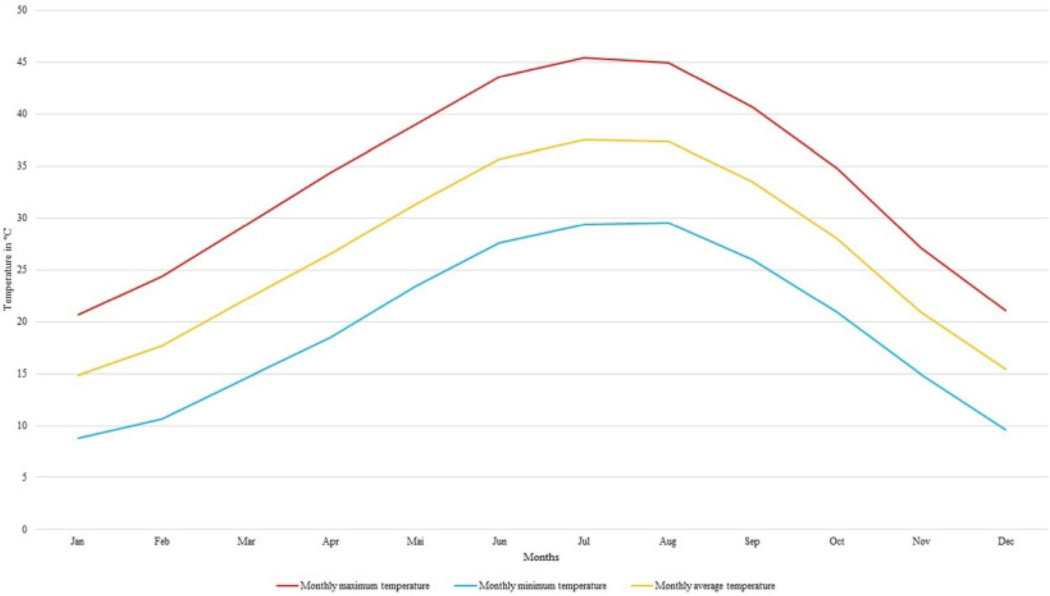

Fig. 4. Monthly maximum, average and minimum temperatures

Table 1. Average seasonal rainfall and index Musset (Crs) for Guemar station between 1978-2020

Seasons	Autumn	Winter	Spring	Summer	Pa
Ps (mm)	19.59	24.86	19.69	3.49	67.63
Crs	1.16	1.47	1.16	0.21	

2020 with 1.34 mm. Furthermore, the station of Guemar recorded 18 years of precipitation above the average and 25 years under the average that is 67.63 mm.

In terms of monthly maximum recorded temperatures over 42 years, July was the hottest month with a maximum temperature of 45.44°C as illustrated in Fig 4. On the other hand, the coldest month was January with 8.83°C as the lowest values of the monthly minimum recorded temperatures, Fig 4. In average, the minimum calculated monthly average temperatures were 14.87°C observed in January, and the maximum calculated monthly average temperatures was 37.53°C observed in July. Furthermore, the annual average temperature was 26.75°C.

Seasonal rainfall regime

The Musset index was used to assess the seasonal rainfall regime from 1978 to 2020. (Table 1). Autumn (September, October, and November), winter (December, January, and February), spring (March, April, and May), and summer (June, July and August) are the four values that stand out for the seasonal rainfall regime. The results clearly show the study area's summer drought with Crs of 0.21 and Ps of 3.49 mm, as it is clear in table 1, the seasonal precipitation pattern is AWSS type.

As it is extremely important, the combination of precipitation and temperature data makes it possible to highlight the dry and wet periods during the year by the Rainfall diagram of Gaussen and Bagnouls. A dry mouth is one in which the average total precipitation (mm) is less than or equal to twice the average temperature (°C) of the same month. This relation makes it possible to establish a Rainfall diagram of Gaussen and Bagnouls on which the temperatures are brought to a double scale of the precipitations. Furthermore, when temperatures go above the precipitation curve, the corresponding

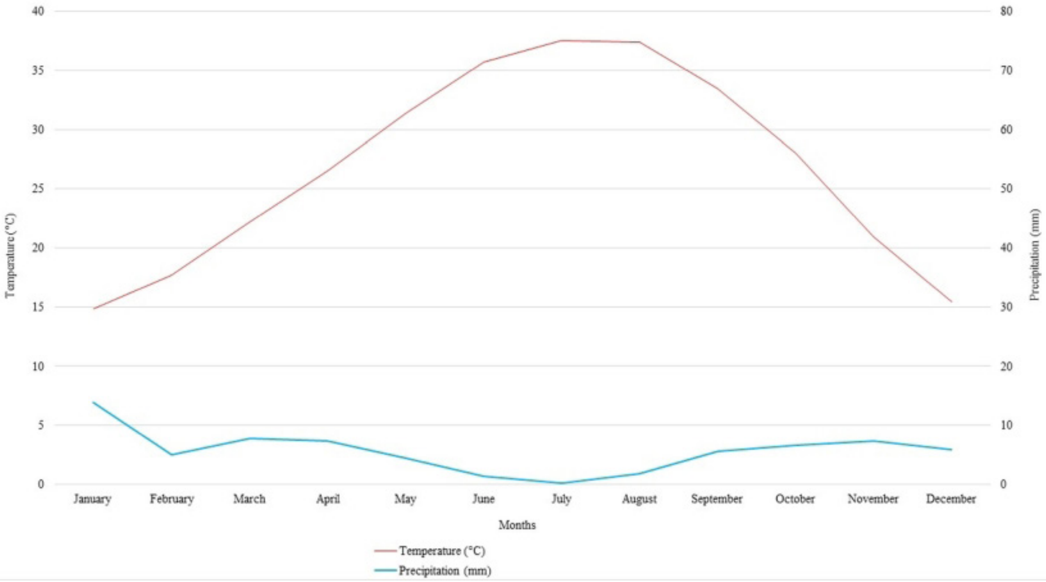

Fig .5. Ombrothermic diagram of Gaussen and Bagnouls for the Guemar station (1978-2020)

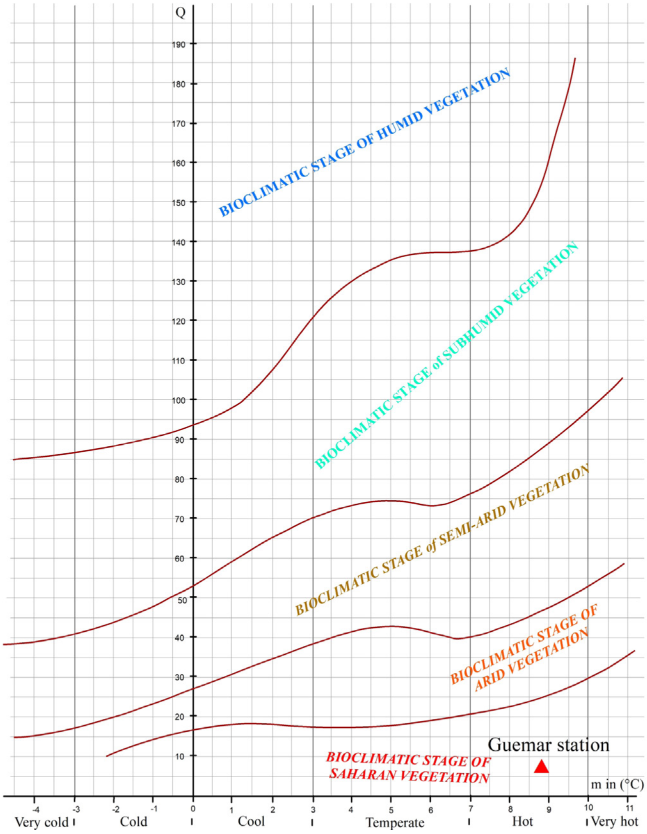

Fig. 6. Emberger climagram for Guemar station

period has a water deficit and when the precipitation curve goes above the temperature curve, the corresponding period is wet. The hydrological year of the study area is branded by the presence of dry period and total absence of wet period over the year, even during January when it was observed lowest temperature and highest precipitation Fig 5.

According to the highest temperature of the hottest month, the lowest temperature of the coldest month and the average of the annual precipitation, the quotient Q2 calculated by Emberger was 6.16. While the value of De Martonne index calculated for the Guemar station during the period 1978-2020 was 0.20 which signifies that Oued Souf is characterized by a hyper-arid climate. Therefore, the position of the Guemar station on the climagram is located in the field of bioclimatic stage of Saharan vegetation as illustrated in Fig 6.

Water budget

Potential evapotranspiration (PET) refers to the theoretical maximum amount of water that would evaporate if there were an unlimited amount of water available to evaporate at the surface. However, the highest annual simulated PET was 2138.1 mm observed in 2017- 2018 while the lowest one was 1597.8 mm in 2008- 2009. However, the minimum monthly average PET was observed during December at 55.5 mm, while the maximum monthly average PET was detected in July with 254.1 mm as it was shown in figure 7. Real evapotranspiration (RET), on the other hand, is the amount of water that actually evaporates from a given surface. Subsequently, it was noted that the values

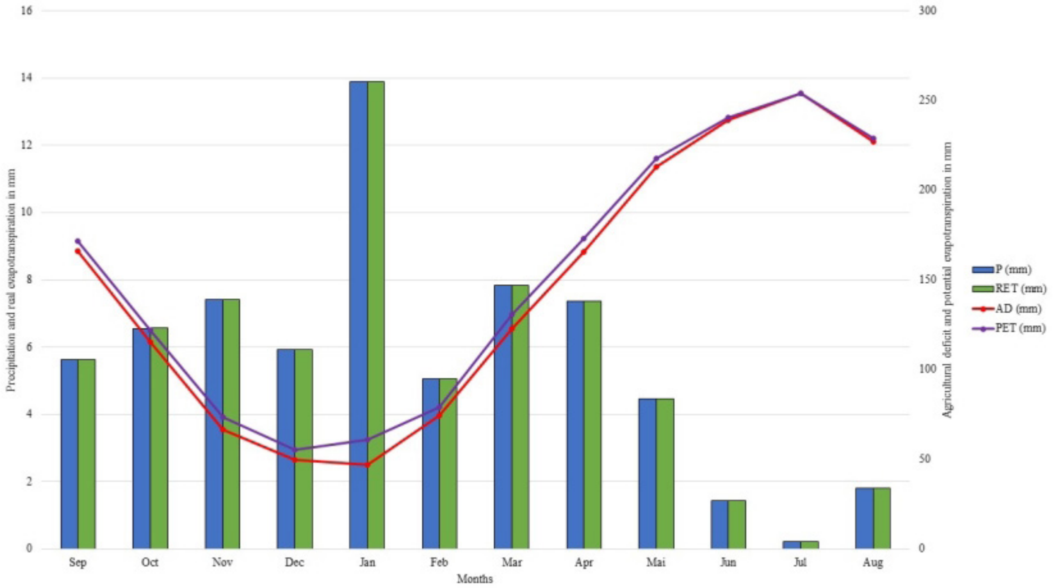

Fig. 7. Water budget parameters over 42 years (1978- 2020)

of RET were lower than the precipitations. After using the easily utilizable reserve (EUR) (Debaeke et al., 1996; Bouchet et al., 1964) that was null over the hydrological year, it was discovered that runoff (R) and the excess (E) are negligible which reflect on the absence of the infiltration (I) can appear due to the evapotranspiration. On the other hand, there is a high agricultural deficit (AD) throughout the year, hence the need for irrigation. All of these results indicated that the hydrological water budget is in deficit during all over the years (Barkat et al., 2022).

4. Conclusion

Based on the study reported in this paper, it was illustrated that a significant increase in drought according to Bagnouls and Gaussen in terms of temperature, the station of Guemar airport is characterized by an extended dry period that appears all over the hydrological year. The rainiest year was 2009 with 233.7 mm, while the driest was 2020 with 1.34 mm. The Emberger quotient calculated during the past 42 years has indicated that the Oued Souf region is in a bioclimatic stage of Saharan vegetation. The irregularity and the scarcity of precipitation, high temperatures and extremely high evapotranspiration which had significant repercussions on surface runoff and infiltration. At the same time and throughout this research, it was revealed that the climatic conditions of the region do not contribute to the natural recharge of the underground reservoirs which implies a big pressure on the socio-economic life and may increase the drought and desertification phenomena.

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