The Spatiotemporal Distribution of Drought in the Region of Batna (Algeria)

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Abstract:

Drought is one of the climatic hazards resulting in significant damage to agricultural yields and occasionally jeopardizing food security drastically, in large parts of the globe. Drought is caused by a protracted rainfall deficit, which can be long enough to have significant impacts on the economic sector of the region. There are considerable indices that have been established for assessing drought, and the most commonly used is the Standardized Precipitation Index (SPI).

In this study, we calculated the index using a high-resolution CHIRPS precipitation data series with a spatial resolution of 0.05 degrees. In addition, the chronological data used in this study, span from 1981 to 2023 and cover the entire region of Batna. It should be noted that the SPI index was calculated after converting the spatial data into point data. Finally, an interpolation was carried out on the results to highlight the spatiotemporal distribution of the phenomenon.

The findings indicate that almost the entire region experienced extreme meteorological drought, during the last five years. This alarming situation requires the implementation of a set of actions to address the consequences of this phenomenon.

Keywords: the meteorological drought, Batna, SPI, CHIRPS, climatic hazards, interpolation.

Introduction:

Drought is a natural phenomenon known for its duration and spatial extent. It is generated by persistent below-normal rainfall with detrimental effects on water resources and on agricultural yields [3-7, 12].

Taking into account the vulnerable issues of huge diversity and the different causes of water scarcity, this phenomenon can be defined in several ways. In other words, there are three types of physical drought that can be distinguished: meteorological drought, hydrological drought, and agricultural drought. Firstly, the meteorological drought arises from atmospheric conditions that can cause a rainfall deficit manifested by an absence or prolonged reduction in precipitation. Secondly, the hydrological drought is characterized by a deficit in river flow and an insufficient level of groundwater and water reservoirs. Thirdly, the Agricultural drought takes place when the level of the soil moisture becomes lower than the supported level required for favorable crop growth conditions. Finally, the socioeconomic drought occurs when the water demand exceeds the available water for the socioeconomic sector [6-8-10-15-17, 20]. In fact, socioeconomic drought typically arises following the other types of physical drought, when water reserves diminish and water demand increases.

Drought is thus defined as a significant water deficit, primarily caused by a scarcity of precipitation over an extended period relative to the average inflows observed during that period [5, 16].

Despite the spectrum of possibilities in which droughts impact the environment, the concept of drought itself remains elusive and beyond comprehension, and to date, it has is no well-established definition [21].

Over the past few decades, numerous specific measures have been developed to detect, monitor, and assess droughts. These indices are typically relevant to a specific type of drought and rely on combinations of data regarding precipitation, temperature, evapotranspiration, or streamflow [20]. One of the most widely used meteorological drought indices is the Standardized Precipitation Index (SPI).

The SPI indicator is used for monitoring and characterizing droughts at different time scales. It is recommended for characterizing meteorological drought on a global scale [1-2-11-12, 19]. The phenomenon commences with the occurrence of negative values in this index and concludes as it shifts to positive values. The main advantage of the SPI lies in the use of precipitation as the sole input for drought assessment [13].

The objective of this study is to assess drought conditions in the province of Batna, Algeria, by utilizing the Climate Hazards Group Infrared Precipitation with Station Data (CHIRPS), a gridded precipitation dataset with a quasi-global resolution of 0.05°. This assessment is conducted through the calculation of the SPI index, using monthly precipitation time series obtained from this dataset (CHIRPS), spanning between 1981 and 2023.

1. Geographical Location of the Study Area

The province of Batna is located in the northeastern part of Algeria, between "4° and 7°" East longitude and "35° and 36°" North latitude. It contains 61 municipalities. The territory of this Wilaya covers an area of 12.038,76 square kilometers (approximately 4,648 square miles).

It almost entirely belongs to a physical set that is shaped by a junction of Tell Atlas in the north and the Atlas Saharien in the south, a feature that significantly contributes to its distinctive physical and climatic characteristics. The province is delineated to the north by the provinces of Oum el Bouaghi, Mila, and Sétif.

To the south, it borders the province of Biskra. The eastern boundary is shared with the province of Khenchela, and M'Sila province lies to the west.

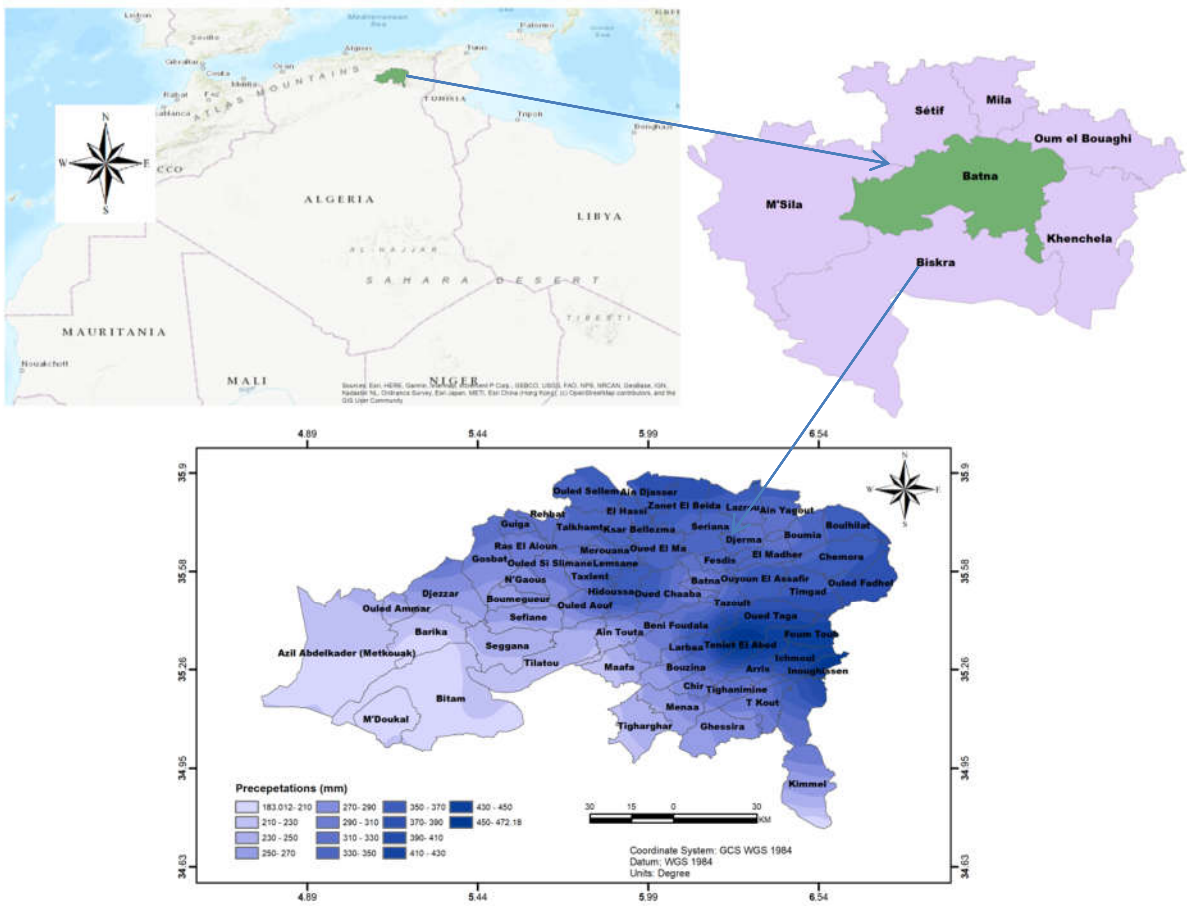

Figure1. Presentation of the study area

The climate of the region is classified as semi-arid, characterized by irregular rainfall. The maximum annual rainfall of around 430 mm is recorded in the municipalities of Oued Taga, Arris, and Fom Toub. In contrast, the minimum annual rainfall of around 183 mm is recorded in the municipalities of M'Doukal, Bitam, and Barika in the southwest of the study area (Figure 1).

2. Materials and Methods.

The Standardized Precipitation Index (SPI) was developed in 1930 by T.B. McKee et al, in order to characterize rainfall deficits within a specific region over a duration that should be long enough. The cumulative water volume for the chosen period is statistically compared to historical data of the same duration, to establish a severity index. Indeed, a continuous series of more than 30 years of observations is required to calculate this index [2]. It should be noted that the SPI is a simple, powerful, and flexible index based solely on rainfall data [9]. It is mathematically expressed as follows:

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

Pi: precipitation in year i (mm)

Pm: average precipitation of the series (mm)

σ : Standard deviation of the series (mm)

Negative SPI values indicate dry periods. In contrast, positive values signify wet conditions. The intensity of these conditions is evaluated on the basis of the index value, as outlined in the table below.

Table 1. Classification of drought according to (SPI) values

SPI Classes	Degree of drought
SPI>2	Extreme humidity
1<SPI<2	High humidity
0<SPI<1	Moderate humidity
-1<SPI<0	Moderate drought
-2<SPI<-1	Severe drought
SPI<-2	Extreme drought

The primary purpose of SPI is analysis for diagnostic purposes; acting as a decision-support tool. It can help authorities and guide decision-makers in establishing the agricultural strategy in a given region.

The pluviometric data for this study were elaborated by the Climate Hazards Group at the University of California, they are accessible through their online repository: (https://www.chc.ucsb.edu/data/chirps). These precipitations are derived from both ground and satellite observations, with a spatial resolution of 0.05°; for the purpose of producing estimations about precipitations, spanning from 1981 to the present. All this comprehensive dataset facilitates the analysis and the monitoring of diverse climatic phenomena, including meteorological drought.

Using the ArcGIS software, we, firstly, identified and extracted the geographical zone that covers largely the territory of the study area from the raster precipitation data. Secondly, we converted all raster precipitation data from the entire available series into vector format points. Subsequently, an attribute join was conducted to assign the precipitation values for all years to each point in a new information layer (Figure 2). At the level of the attribute table of the new information layer, we created fields to calculate the mean and the standard deviation for the statistical data assigned to each point.

Finally, a last data field was created on the attribute table of the same information layer, and the SPI index values were calculated for each point according to the formula above.

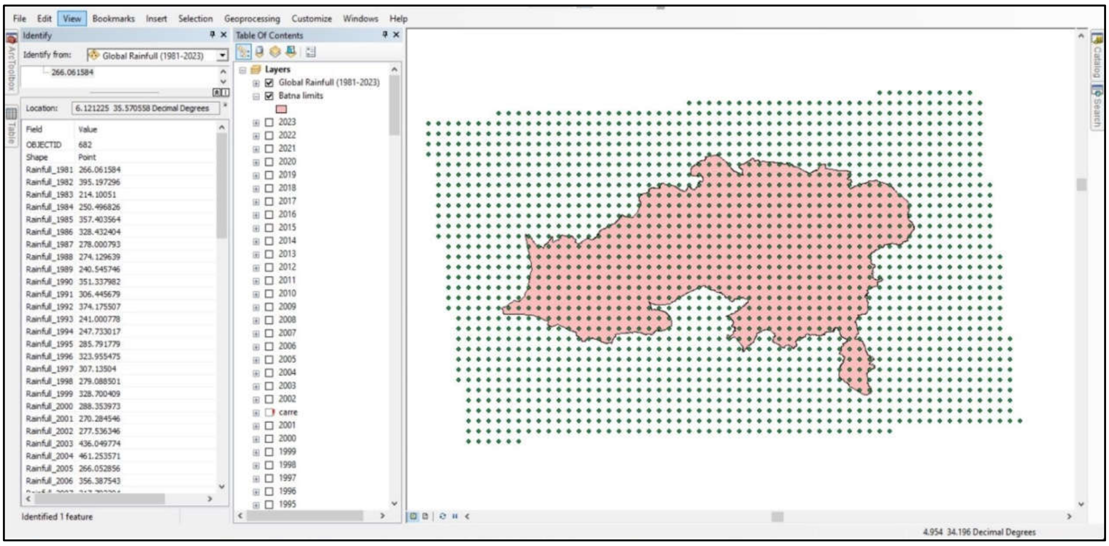

Figure2. Data preparation under ArcGIS software

The discrete spatial knowledge of SPI values is insufficient, or less obvious to visualize, more notably during the interpretability of this phenomenon of drought. These values therefore necessitate interpolation in space to bring the spatial distribution of this phenomenon to light.

Ordinary kriging, a stochastic interpolation technique, is considered as the most effective method with a high degree of accuracy and representativeness in characterizing the spatial distribution of precipitation, and in characterizing the phenomena that emerge as a consequence, as evidenced by the literature and multiple prior investigations [4-14, 18].

1. Results and Discussion.

After the statistical calculation of the index values, and the creation of the cartography relating to the spatial distribution of the results, our analysis revealed a progressive intensification of meteorological drought conditions that has been observed over the past five years, over the whole study area (Table 2). It is noted that the SPI indicator is very adequate for characterizing the different phases of drought.

In 2018, the drought affected almost the entire central and southern parts of the province of Batna. In 2019, the eastern and southern parts of the province were affected. From 2019 to 2023, the entire territory was gradually affected, (Figure 3).

Indeed, the most significant peaks of the SPI indicator during this period are negative (Figure 4). Furthermore, this meteorological drought persistency has caused hydrological and edaphic drought. According to testimonies, a substantial decline in water resources has been well observed across the entire territory. As far as the agricultural yields are concerned, they have experienced a notable decline throughout this arid period.

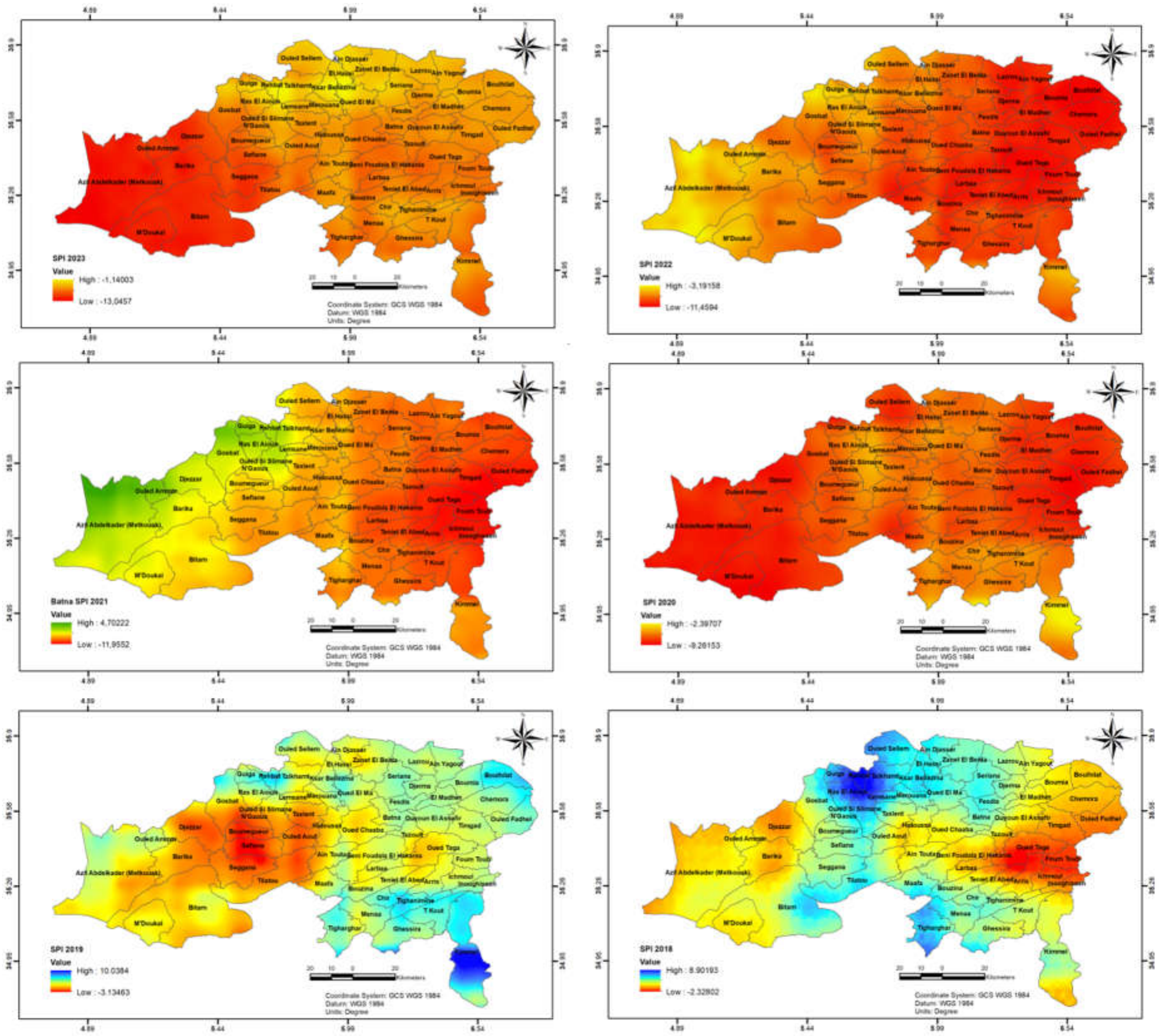

Figure3. The spatial distribution of meteorological drought between 2018 and 2023

Table 2. Average SPI values across the entire study area.

Years	Average of SPI values
2018	1.379
2019	3.1
2020	-4.451
2021	-5.752
2022	-7.22
2023	-7.619

According to the table above, the entire region experienced a very severe and progressive drought during the three four-year period spanning 2020 to 2023.

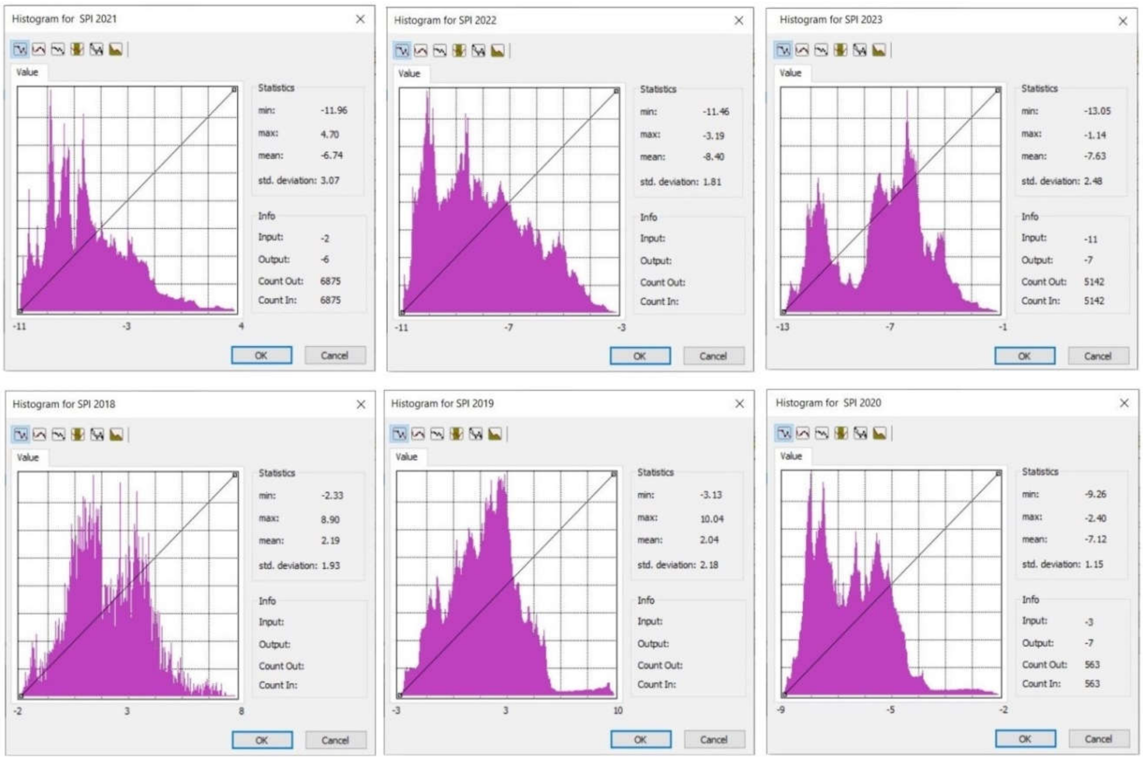

Figure4. SPI values between 2018 and 2023.

Conclusion:

The research focused on the spatial distribution of meteorological drought in the territory of the province of Batna, from 2018 to 2023.

The SPI index Analysis reveals that the region endured a period of severe and progressive drought over this timeframe (2020-2023). It is also noteworthy that this index is impactful and reliable, providing a clear insight into the degree of drought in a given location. In addition, the database developed by the Climate Hazards Group constitutes is a reliable source of relevant information, providing a dataset for a relatively long period, which enables the examination and the analysis of various meteorological phenomena.

In conclusion, this study can serve as a support and a decision-making tool for authorities and farmers, in this region, to effectively carry out their actions.

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