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Urban Dynamic and Environmental Stakes Monitoring Socioeconomic Drought, Google Earth Engine Approach: The Case of Bordj Bou Arreridj City

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Abstract

Algeria has recently experienced successive droughts, which pose social and economic issues and challenges to decision-makers, represent a major threat to urban water supply systems, and affect the response of its internal and external urban dynamics. Through this research, we will try to address the diagnosis of the effects of drought on the urban system of the city of Bordj Bou Arreridj, located in the western extension of the eastern high plains most affected by drought. Natural Vegetation (SVI), and study the association between them, where the historical dry periods were from 2000 to 2020, also based on CHIRPS climate data. The research concluded that the semi-arid climate has become the prevailing climate in a large part of the state region, and the consequences related to water shortage in urban areas have affected the process of social and economic transformations. The research also concluded with the recorded deterioration in the values of urban ecosystems, which is confirmed by the high indicators of pollution and desertification manifestations in the urban environment. The analysis also showed a good agreement with the recorded drought periods. And the extent of its impact on changing the socio-economic structure of the city, and the nature of urban land use. Through this research, we seek to highlight the role of the drought phenomenon in the changes taking place in our cities and to open questions about how models and scenarios of preparation should be drawn up in the future to reduce the negative effects of drought.

Keywords: Bordj Bou Arreridj, semi-arid climate, urban system, urban dynamic, urban environment.

INTRODUCTION

Following independence, the departure of Europeans led to an unprecedented rural exodus (Boukhemis and Zeghiche, 1988). This migratory movement was directed not only towards the cities but also towards villages and towns that did not have a pronounced urban character. This was determined by a strong regrouping of the population (32.63%) without being able to adapt to urbanization as such. It did not meet the criteria established for urban centers. This massive and brutal demographic transfer generated great demographic and socio-economic disparities, resulting in a very heavy burden within the urban space and the integration of a large part of the population into the economy and the urban reality. This phenomenon of population concentration, which is not linked to modern economic or industrial development, has not allowed cities to develop harmoniously and has made them more like centers of consumption. It has not allowed cities to develop harmoniously and has turned them into centers of consumption instead of production. (ONS, 1988, p. 21). Here, the urban phenomenon is mainly of demographic origin, it can be assimilated to a fairly rapid concentration of the population and, contrary to what is observed in the industrialized countries, urbanization preceded industrialization. Also, demographic development has largely determined economic policy and governed all government planning and development projects (Rahmani, 1982, p. 27).

Climatically, Algeria belongs to the arid, semi-arid triangle. Drought and aridity are a constant danger, even in humid regions where the annual rainfall rate appears high (coastal areas), and the continental character is strongly observed in a large part of the cultivated area.

Algeria was an essentially rural country at the end of the colonial period (1830-1962), and the process of urbanization has not yet been completed. The study of land use is one of the most important means for the planning and management of spaces, given the high population and its urban expansion in various urban activities on green spaces and agricultural lands in the commune of Bordj Bou Arreridj.

The cereal growing system constitutes 80% of the cultivated land. And it represents only 29% of the exploited agricultural surfaces (SAU) for cereals alone. And it is located in areas where little more than 450 mm of rainfall falls per year, which explains the low yield (7 cents per hectare) recorded over the last few decades. Climatic changes show the instability of the level of production recorded from year to year (the cereal product fell from 38 million quintals in 1991 to less than 10 million quintals in 1994). The choice of intensifying agriculture in Algeria has become very difficult, given the deficit recorded in the rate of rainfall and its fluctuation, which is what distinguishes the eastern high plains where the study area is located

Through this research, we seek to highlight the role of the drought phenomenon in the socio-economic mutations that are taking place in our cities and to open up questions on how to create models and preparation scenarios that should be highlighted in the future to reduce the negative effects of drought.

OBJECTIVES

This study assumes that the drought phenomenon has severely affected the urban dynamics of the city of Bordj Bou Arreridj, and has negatively affected the agricultural lands and that the drought as a natural phenomenon enters as a dependent variable in the social and economic transformation, knowing that the study area belongs to the arid region. The predominant activity from colonialism until after independence is cereal cultivation and grazing. The repeated periods of drought have directly affected the agricultural yield, and with the availability of other economic opportunities through the adjustment of development policies, the creation of the industrial zone and the commercial activity zone, they have made the area more attractive for the population, especially the neighboring rural areas that belong to the steppes.

Its urban fabric has evolved rapidly in a short period, and we will follow the urbanization of this city from 1984 to 2021, and preview the land-use changes based on the Google Earth Engine (GEE) which provides a quick and easy-to-use tool. platform with its geo-analysis tools. Based on Landsat 5 and Sentinel-2 satellite images for several periods.

This transformation that has taken place in the region can be seen as a kind of resilience to this phenomenon, but the problem of drought remains a problem to which solutions must be sought.

Therefore, the objective of this scientific paper was:

- To monitor drought and estimate drought-prone areas and try to understand and predict its occurrence to help develop plans to manage and reduce its occurrence and impact. Where this apparent study has been carried out is in the area of the state region, where the study area is located.
- To follow the evolution of land use over 40 years, to see the different changes that are taking place at the spatial level and in the functions that the city has become during this period.

Definition of Drought

- As this phenomenon affects many aspects of human life, we find that the definition of drought varies from one discipline to another, depending on the purpose and criteria chosen.
- "According to Palmer: Drought means different things to different people, depending on their particular interest. To the farmer, drought means a lack of moisture in the root zone of his crops. For the hydrologist, it suggests below-average water levels in rivers, lakes, and reservoirs. For the economist, it means a shortage of water that hurts the established economy"[1].
- Wilhite and Glantz have developed over 150 published definitions. They describe drought conceptually (as an idea or concept) and operationally (through the way drought works or in a measurable way). But in general, drought can be defined as a long period of insufficient precipitation that lasts for one or more seasons or even several years, resulting in water shortages in certain economic sectors of a country[2].
- The United States Weather Service defines a drought as a significant and continuous lack of precipitation that can affect the life of local flora and fauna and deplete water supplies, whether for household needs or power plant
- operation, especially in areas where precipitation is generally sufficient for these purposes[3].

1 Gao, Z.; Gao, W.; Chang, N. B. (2011). Integrating Temperature Vegetation Dryness Index (TVDI) And Regional Water Stress Index (RWSI) For Drought Assessment with The Aid of Landsat TM/ETM+ Images. International Journal of Applied Earth Observation and Geoinformation. (13), 495–503.

2 Eriyagama, N.; Smakhtin, V.; Gamage, N. (2009). Mapping Drought Patterns and Impacts: A Global Perspective. International Water Management Institute: Colombo, Sri Lanka (IWMI Research Report 133).

3 Giorgi, F. (2006). Climate Change Hot-Spots. In: Geophysical Research Letters (33), April 2006.

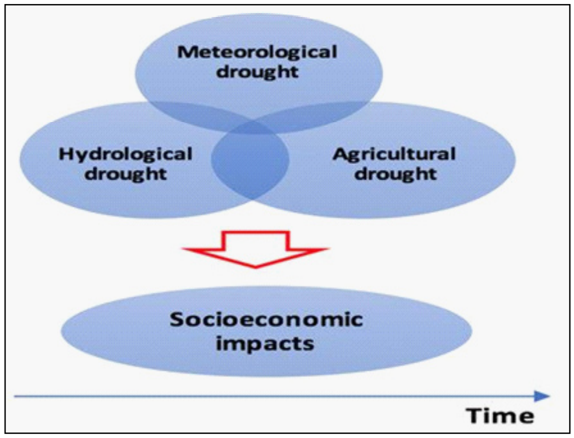


Figure 1. Interrelationships between the initial meteorological drought, followed by the cascade of successive forms of agricultural, hydrological, socio-economic, and political drought (After National Drought Mitigation Center, University of Nebraska - Lincoln, USA, in WMO, 2006).

METHODOLOGY AND TOOL

Study Area

-It is the capital of the wilaya of Borj Bou Arreridj is located in the middle of the territory of the wilaya. It is considered one of the 34 communes of the wilaya. Administratively, it represents the location and consists of two secondary communities, which are Bir al-Sanab and Ain Zeraiqa naturally occupies the following positions:

- It is bordered by the commune of Mejana to the north.
- It is bordered to the east by the municipality of Sidi Mubarak.
- It is bordered to the west by the municipality of El-yashir and the south by the municipality of Hammadia and the elements.

-Geographically Borj Bou Arreridj is a part of the high plains of the East, between the two mountains of the Tellian Atlas represented by the mountain range of El-biban, it is a homogeneous unit, ranging from 1200 to 1750 m in altitude, In the south is the mountain range Al-hodna, which includes the northwestern end of the mass of Al-Maadid, which is the highest peak of 1885 m at Mount Chellinge, Taglait commune, as well as the mountains of Al-ach and the mountain of Bordj Ghdir which separates the two groups and the valley of Oued Elksob. From the east, it is surrounded by the area of the upper plains towards the Sabia plains.

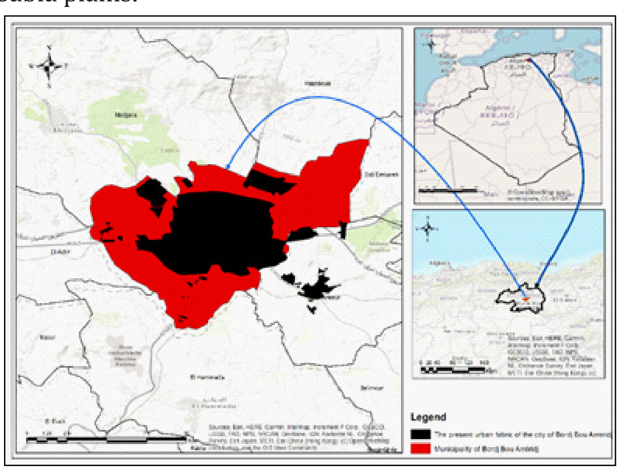


Figure 2. Geographical situation of the city of Bordj Bou Arreridj

This study examines the possibility of using the two drought-based standard precipitation indicators (ISP) for drought frequency, and the natural vegetation cover index (SVI) for the same region and period, and studies the correlation between them, where historical drought periods were examined from 2000 to 2021, and the analysis shows good agreement with recorded dry periods. This study was conducted using the Google Earth Engine approach to spatially apply and map the indices and also rely on CHIRPS climate data.

The Birth of Bordj Bou Arreridj City

The first nucleus of the city of Bordj Bou Arreridj was formed in the center of the wilaya, as it dates back to the colonial period, which is characterized by its colonial architectural character and the rectilinear road network, which was a characteristic of most Algerian cities at the time. Then the city underwent a rapid urban expansion after independence in all directions (see Fig. No.), so that some chaotic neighborhoods appeared, such as Al-Jabbas, the market roundabout, Al-Faybour, La Graf, Al-Batwar, the district of 08 May 1945, and the former garden district. Then the industrial zone appeared on the southern side, and then the first urban residential zone appeared on the eastern side. It consists of 400 dwellings, then individual dwellings started to appear in fragments on the western side, such as the Tayeb Khairah fragmentation (12 hectares). Subsequently, the urban growth of the city stopped on the three sides, east, south and west, due to the presence of obstacles preventing urban sprawl, including:

- Natural barriers: represented in the valley and the Boumrkad forest on the eastern side.

- Industrial barriers: medium voltage lines on the west side, and the industrial area on the south side.

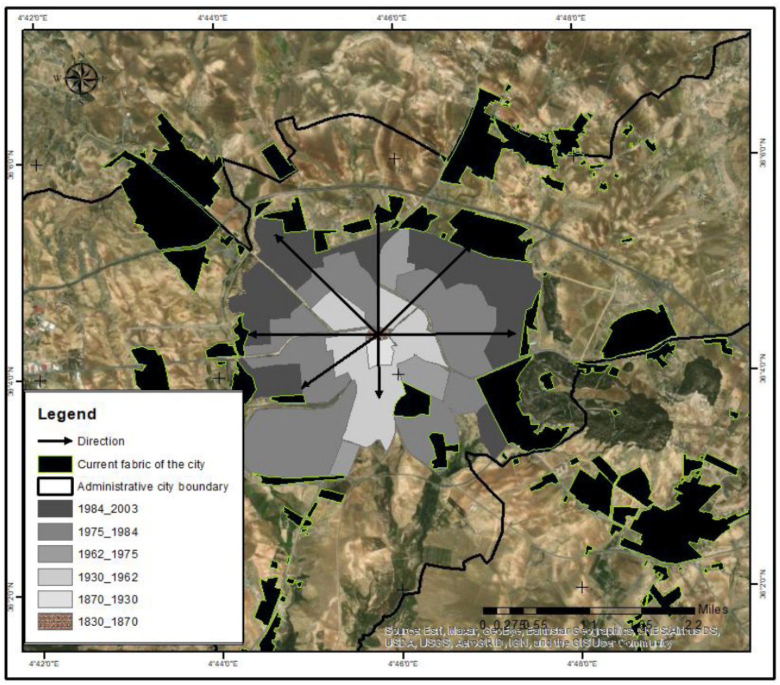


Figure 3. The historical development of the urban fabric of the city of Bordj Bou Arreridj (1830-2003) according to urban plans.

Economic Transition in the City of Borj Bou Arreridj

From the first ten years of independence, in order to achieve territorial balance, the regional planning programs tended to promote the Eastern High Plains, according to M. C MTE (1988), this area was favored because of cereal crops and a population density of 60 inhabitants/km2.

All the cities of the region, especially Setif, have industrial zones, airports, social services and administrative foundations necessary for the territorial framework, and the reinforcement of road and railway infrastructures.

The city of Borj Bou Arreridj should become a dynamic center of the region following the example of other neighboring areas (Sétif and El Alama), where the population is growing rapidly, is promoted to chief town, and offers 173 hectares of industrial space from the first stage of the organization of the facilities and the national industrial policy.

The adoption of the capitalist and free-market system and the change in the role of the state in the development process from manager to overseer (1987-1988) had no effect on the economic dynamics of the city, on the contrary. It has particularly attracted private investors oriented towards the industrial sector. Through the establishment of small and medium-sized enterprises, it has seen the intensification of the industrial structure and the diversification of products and has been accompanied by a significant exodus of the rural population, which has been absorbed mainly by the city.

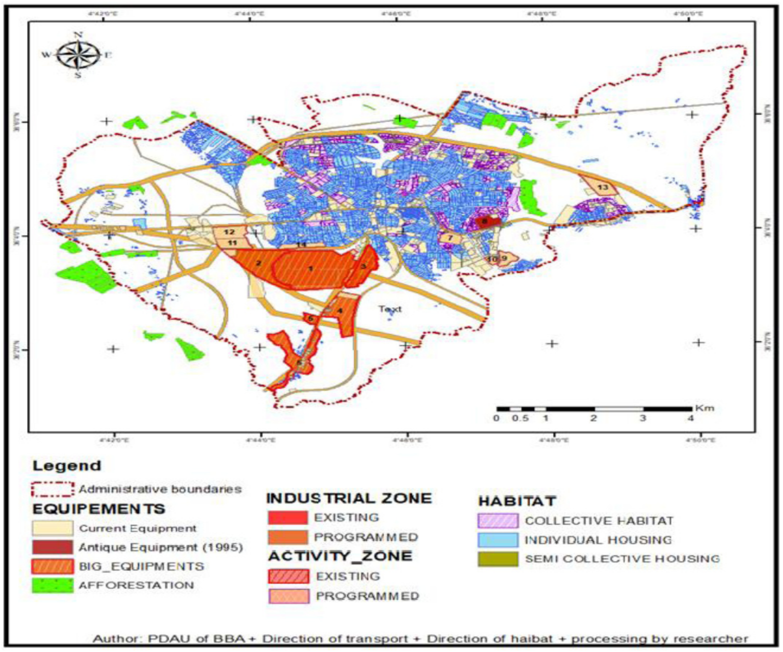


Figure 4. Land use plan for the Bordj Bou Arreridj city

The Most Important Source of Water for the Study Area is the Case of Ain Zada Dam

The Ain Zada dam is located along the Wilayas of Sétif and Bordj Bou Arreridj, 40 km north of the state capital of the Wilaya Bordj Bou Arreridj and 25 km west of the state capital of Sétif. It is located 11 km northeast of the village of Ain Tagrout in the Bouslam valley. It is located between the Armistice Mountain to the south and the Kabyle Mountains to the north.

The Ain Zada dam has recently experienced a dramatic drop in water level, which has caused the dam to dry up, and pumping operations have stopped, with the dam reaching the dead volume level, which prevents pumping and remains protected for the dam.

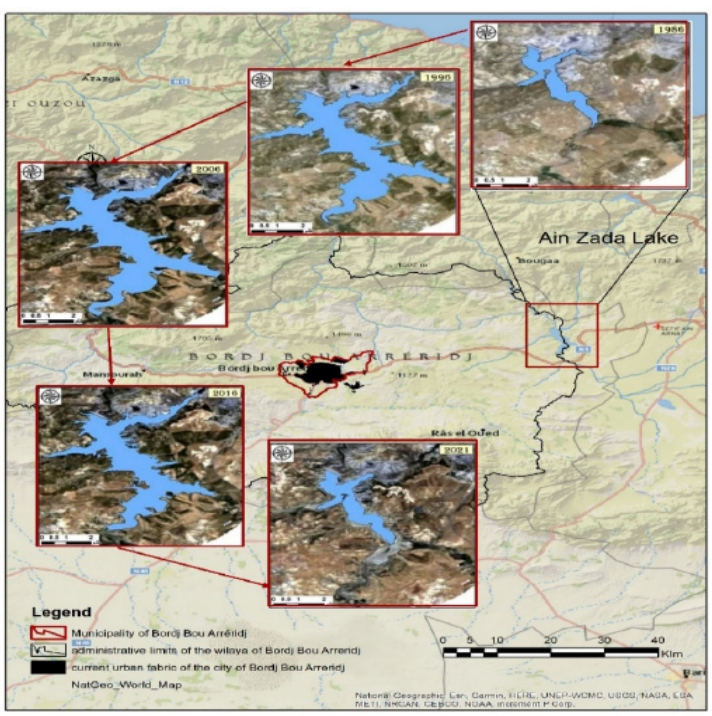


Figure 5. Water area changes of Ain Zada Lake from 1986-2021 (Wilaya of Bordj Bou Arreridj

Water Area Changes of Ain Zada Lake From 1986-2021 (Wilaya of Bordj Bou Arreridj)[4]

Years	Surface (klm2)	Difference
1986	2.60	/
1996	9.60	+7
2006	10.29	+0.69
2016	8.98	-1.31
2021	2.70	-6.28

Source: USGS US Geological Survey website +personal work

Drought Study in the Study Area

This study examines the possibility of using the two drought-based standard precipitation indicators (ISP) for drought frequency, and the natural vegetation cover index (SVI) for the same region and period, and studies the correlation between them, where historical drought periods were examined from 2000 to 2021, and the analysis shows good agreement with recorded dry periods. This study was conducted using the Google Earth Engine approach to spatially apply and map the indices and also rely on CHIRPS climate data.

Drought and the Standardized Precipitation Index (SPI)

It is important to explain what drought indicators mean. Indicators: are variables or parameters used to describe drought conditions. These include, for example, precipitation, temperature, river flow, groundwater and reservoir levels, soil moisture, and snow deposits. They are most often a numerical representation of drought intensity. These indicators are calculated based on climatic or hydrometeorological values and measure the qualitative state of drought in a given location over some time. Climate monitoring at different time scales can detect short wet spells during long dry spells or short dry spells during long wet spells.

Intensity thresholds can be defined, when the drought starts, when it ends, and which area may be affected. The location refers to the geographical area experiencing the drought conditions. The time and duration of occurrence refer to the approximate date of the event. The impact depends on the combination of the disaster itself, the elements exposed to the disaster (people, agricultural land, reservoirs, water supply, and the vulnerability of these elements). Past droughts may have increased vulnerabilities. The duration and intensity of the drought may determine the impact. Short-term droughts of moderate intensity that occur when mature crops are sensitive to moisture can sometimes have destructive effects, while long-term severe droughts occur at less critical points in the production cycle.

The Standardized Precipitation Index (SPI)

The method used to calculate the PSI was developed by Thomas B. McKee of Colorado State University and his colleagues in 1993[5] It reflects the impact of drought on the environment, and is used to assess the impact of drought on the environment. It reflects the impact of drought on the availability of different water resources (groundwater, storage reservoir, soil moisture, snow cover, and river flow)[6]. It is a statistical indicator used to characterize local or regional drought. Based on long-term precipitation history, PSI quantifies the difference between the precipitation, deficit, or surplus in a period and the historical average precipitation in that period. This period usually varies from 3 months to 2 years, depending on the type of drought one wishes to monitor.

PSI is powerful, flexible, and easy to calculate the index. The precipitation data is the only parameter required. Moreover, the PSI is equally effective in analyzing wet periods or cycles as well as dry periods or cycles. To calculate the PSI, the ideal situation is that the monthly readings extend over at least 20-30 years, but preferably over 50-60 years, which is the best period.

4 The Ain Zada dam was established in 1986 on the Bouslam valley, and was initially intended for irrigation, but was converted to supply the towns of Sétif, Bougaa, El Alama and Bordj Bou Arreridj with drinking water (from 125 Hm^3).

5 McKee TB, Doesken NJ, Kliest J, (1993), The relationship of drought frequency and duration to time scales, Colorado Climate Center Department of Atmospheric Science Colorado State University-Fort Collins, pp 43-50, Colorado.

6 P. Angelidis, F.Maris, N.Vlassiois, (2011), Computation of Drought index SPI with Alternative distribution function, international journal of climatology, pp 28-30

Climate Data

Climate Hazards Group Infrared Precipitation with Station Data (Chirps)

Is a near-global rainfall dataset of over 30 years. CHIRPS integrates satellite imagery with 0.05° resolution with in situ station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring.

The ISP is used as it highlights the difference from the average precipitation over a given time and therefore provides information on drought conditions. The script will be executed in Google Earth Engine and will run on two independent PSI calculations. The first calculation is for the "common" PSI, which is calculated on an "n" month basis. An ISP, which is calculated for one month, usually refers to the description "ISP-1", for six months "ISP-6" and so on. The second ISP calculation is based on MODIS capture dates. As MODIS provides information on vegetation, it can be useful to compare its vegetation indices with the PSI. Therefore, a PSI of 16 days is calculated, the start date of which corresponds to the start date of MODIS.

Google Earth Engine (Gee)

This is a web-based platform for the cloud-based processing of large-scale remote sensing data. The advantage is its remarkable computational speed as the processing is outsourced to Google's servers. The platform provides a variety of constantly updated datasets; no raw image downloads are required. Although it is free, access to Google Earth Engine must always be activated with a valid Google account. Confirmation is usually received within 2-3 business days.

Calculation Method

In theory, the PSI is the number of standard deviations that an event is far from the mean, which is often called the z-score calculated from the CHIRPS precipitation values for each pixel location of a composite period for each year during a given reference period. The equation below shows the general calculation of the PSI.

$$SPI_{ijk} = \frac{P_{ijk} - P_{ij}}{\sigma_{ij}}$$

Where: SPI_{ijk} is the z-value of pixel i in period j for year k,

P_{ijk} is the precipitation value for pixel i in period j for year k,

P_{ij} is the average for pixel i in period j over n years,

σ_{ij} is the standard deviation of pixel i during week j over n years.

While precipitation data are generally not normally distributed, especially when dealing with periods of 12 months or less, a transformation has to be applied. The data is usually fitted to a gamma function.

Table 1. PSI and the corresponding cumulative probability about the base period[7]

PSI Index	Category	Number of times over 100 years	Frequency
From 0 to -0.99	Slight drought	33	1 time every 3 years
From -1.00 to -1.49	Moderate drought	10	1 time every 10 years
From -1.5 to -1.99	Severe drought	5	1 every 20 years
< -2.0	Extreme drought	2	1 time every 50 years

McKee (1993) uses the classification shown in Table 02 to define drought intensity using the PSI.

Table 2. Classification of droughts according to PSI values

PSI value	Drought sequence
2.0 and above	Extremely wet
1.5 to 1.99	Very wet

7 McKee TB, Doesken NJ, Kliest J, (1993), The relationship of drought frequency and duration to time scales, Colorado Climate Center Department of Atmospheric Science Colorado State University-Fort Collins, pp 43-50, Colorado.

from 1.0 to 1.49	Moderately wet
from -0.99 to 0.99	Near normal
from -1.0 to -1.49	Moderately dry
from -1.5 to -1.99	Very dry
-2.0 and below	Extremely dry

Standardized Vegetation Index (SVI)

The SVI is used for drought monitoring and drought warning. This index describes the probability of change of the normal NDVI over weekly time intervals for several years of data (Peters et al., 2002). SVI is the deviation of the z-score from the mean, in standard deviations, based on the NDVI (Normalized Difference Vegetation Index) and EVI (Enhanced Vegetation Index) values for each pixel location for each compound period per year within a given reference period. The SVI formula is as follows (UN-SPIDER, 2020):

$$Z_{ijk} = \frac{VI_{ij} - \mu_{ij}}{\sigma_{ij}}$$

Where: Z_{ijk} is the z-value of pixel i during week j for year k, VI_{ij} is the weekly VI (vegetation index) value for pixel i during week j for year k, thus both NDVI and EVI (Son et al., 2014) can be used as VI, μij is the mean of pixel i during week j for n years, and σ_{ij} is the standardized deviation of pixel i during week j for n years. This formula was established to obtain data every week; however, due to the temporal resolution of the satellite used in this study, measurements are taken every 16 days.

For NDVI and EVI calculations (Son et al., 2014)

NDVI = (Pnir - Pred)/(Pnir - Pred)

EVI = (2.5*Pnir - Pred)/(Pnir + 6*Pred - 7.5*Pblue + 1')

Where: Pred: (620-670 nm), Pnir (841-876 nm), and Pblue (459-479 nm) are MODIS bands 1, 2, and 3. The calculation of the SVI is based on the EVI, which in turn is obtained from the corrected NDVI, has improved sensitivity under dense vegetation conditions, and is less affected by the influence of aerosols (Wang et al., 2012). The random variable of a standardized normal distribution corresponds to a Z-score. Therefore; each random variable X can be transformed into a Z-score by the following equation (UN-SPIDER, 2020)[8]:

$$Z = \frac{(X - \mu)}{\sigma}$$

Where: X is a normal random variable, is the mean, and is the standard deviation. Therefore, a Z-score of 0 represents an item equal to the mean, a Z-score of less than 0 represents an item below the mean and a Z-score of more than 0 represents an item above the mean. The Z-score indicates the number of standard deviations of an item from the mean, so the standard deviation, in general, indicates how dispersed the data set is (Peters et al., 2002). A low standard deviation implies that the data are closely clustered around the mean, while a high standard deviation implies that the data are spread over a wider range of values. If the number of items in the data set is large, about 68% of the data are within 1 standard deviation of the mean, 95% within 2 standard deviations, and 99.7% within 3 standard deviations of the mean, when it is a Normal Distribution. The IVS was represented in five categories (Table 1) (UN-SPIDER, 2020): green-coloured IVS ≥ 0 (No drought), yellow-coloured -0.10 to -0.94 (light drought), light orange-coloured -0.95 to -1.44 (moderate drought), dark orange-coloured -1.45 to -1.94 (severe drought) and red-coloured ≤ -1.95 (extreme drought). The dynamics of IVS can be influenced by precipitation, stress, phenology, flooding, pests and diseases, nutrient deficiencies, forest fires, grazing, and human activities (Ji Peters, 2003). However, the above-mentioned factors need to be associated with drought types as well as duration, magnitude, intensity, severity, geographical extent, and frequency to understand droughts (Zargar et al., 2011). Finally, we used the coefficient of variation to determine the statistical measure of the dispersion of data points around the calculated IVS mean and box plots to show the dispersion of IVS data across the study areas. These box plots are a standardized method of plotting a series of numerical IVS data across their quartiles.

8 https://www.un-spider.org/advisory-support/recommended-practices/recommended-practice-agricultural-drought-monitoring-svi

Table 3. Drought classes according to the value of the standardized vegetation index (SVI)[9]

Class	SVI Value	Colour
Extreme dryness ≤ -1.95	≤ -1.95	
Severe drought -1.45 a -1.94	-1.45 a -1.94	
Moderate drought -0.95 a -1.44	-0.95 a -1.44	
Light drought -0.10 to -0.94	-0.10 a -0.94	
No drought ≥ 0	≥ 0	

Land-Use Change in the Study Area

Various methods for measuring land-use change have been developed and introduced. For our work, this was done using the supervised classification method. Three categories that we need in our study were derived: lands, vegetation, and urban. This is done by a script that has a set of functions, the most important of which are:

- The first steps in accessing and obtaining the data started with a recall function and the creation of a composite image of a series of images.
- A function to select a group of satellite images (Landsat 5 and 8 SR)
- A filter function by date of interest (1984-2020), and another to mask clouds using the QA pixel cloud range value available in SR products.
- Transfer and export images to ArcMap 10.5 for analysis, processing, and final extraction
- Conduct in-depth qualitative and quantitative analysis and discussion and conclusion.

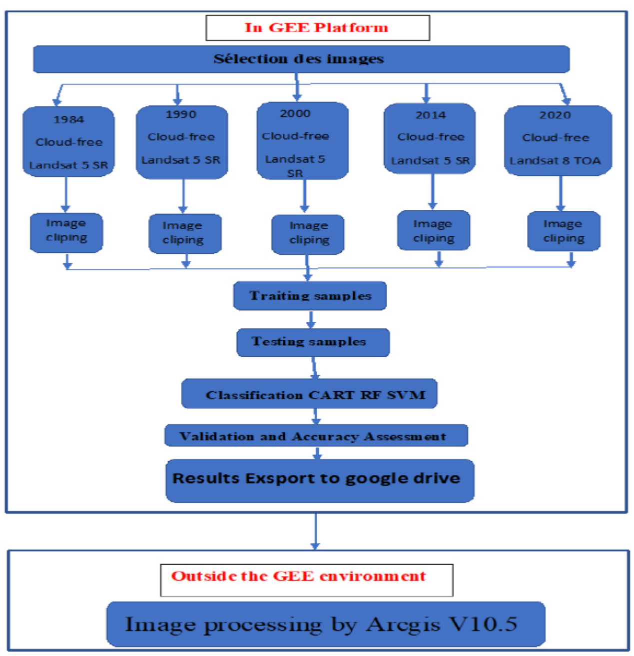


Figure 6. Methodology adopted for the study of the Land-use change.

Standardised Precipitation Index (SPI)

- The Standardised Precipitation Index (SPI) has been calculated with a monthly, seasonal, and annual scale of average rainfall data for Bordj Bou Arreridj from 1981 to 2020 through

9 Jaris E. Veneros and Ligia García (2022), APPLICATION OF THE STANDARDIZED VEGETATION INDEX (SVI) AND GOOGLE EARTH ENGINE (GEE) FOR DROUGHT MANAGEMENT IN PERU. Tropical and Subtropical Agroecosystems 25. (Pp 4)

Annual Scale

Table 4. Shows the annual PSI values for the BBA region over the period (1981-2020).

Years	SPI-12	Years	SPI-12	Years	SPI-12	Years	SPI-12
1981		1991		2001		2011	
1982		1992		2002		2012	
1983		1993		2003		2013	
1984		1994		2004		2014	
1985		1995		2005		2015	
1986		1996		2006		2016	
1987		1997		2007		2017	
1988		1998		2008		2018	
1989		1999		2009		2019	
1990		2000		2010		2020	

Legend

PSI value	Drought Sequence	Legend
2.0 and above	Extremely wet	
1.5 to 1.99	Very wet	
from 1.0 to 1.49	Moderately wet	
from -0.99 to 0.99	Near normal	
from -1.0 to -1.49	Moderately dry	
from -1.5 to -1.99	Very dry	
-2.0 and below	Extremely dry	

Interpretation

The comparison of our results with the drought severity table (Mckee et al., 1993).

We observed periods of

- Two Extremely wet years 1981, 2002 (PSI equal to 2.155, 2.086).

- The Very wet year 2006 (PSI equal to 1.753).

- One year Moderately wet 2012, PSI equal to 1.08.

- 31 years Near normal with PSI between -0.464 and -0.997.

- Three Moderately dry years 2001, 2015, and 2019 with a PSI equal to -1.49, -1.045, -1.226 successively

- The very dry year in 2016 with a PSI of -1.557.

- One extremely dry year, 1982 (PSI equal to -2.57).

The figure below which represents the annual ISP for the BBA region from the 40 years of Climate Hazards Group Infra Red Precipitation with Station data (CHIRPS) has revealed:

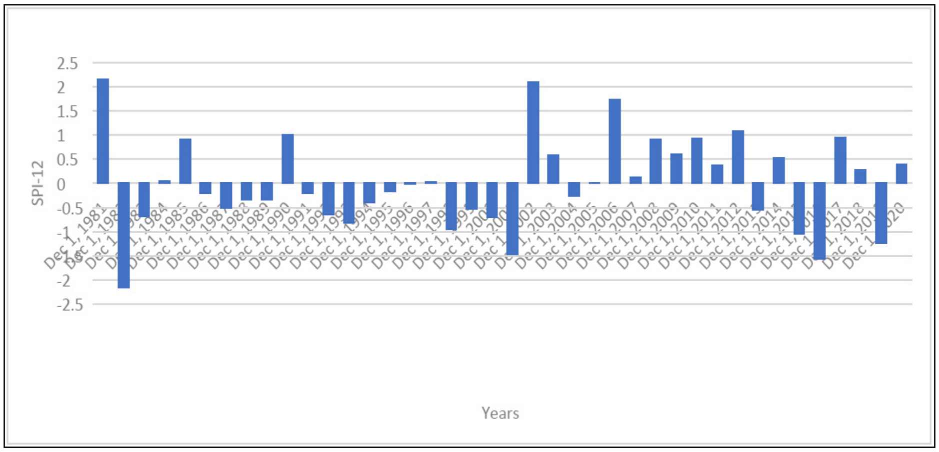


Figure 7. Evolution of annual drought intensity (PSI) during the period (1981 - 2020).

It can be seen that the region has gone through the following periods:

- The graph shows that 20 years in the studied time series from 1981 to 2020 are below the average, and there is a sequence of drought years 1982 and 1983 as the first drought period, 1998, 1999, 2000, 2001 as the second period, and 2015 and 2016 as a third drought period.
- During 12 years the PSI varies between (0 and - 0.99), the region suffers a slight drought, with a repetition of 12 times over 40 years.
- In the year 1983 PSI varies from -1 to -1.49, the drought will be moderate, repeated 1 time during 40 years.
- In the year 1993 a severe drought is observed where the PSI reaches a value of -1.99, then the region experiences 1 drought period in 40 years.
- During the study period (1981-2020), the PSI value reaches a value of -2 (or less) twice, so the region experiences an extreme drought in the years 2001 and 2016.
- The year 2001 is considered to be the most affected by drought compared to 2016 as it was preceded by three consecutive dry years, namely 1998, 1999, and 2000 with PSI values (-0.997, -0.105, -0.717). There have therefore been four consecutive years characterized by drought.

Characterization of Drought

The proportional distribution of the calculated annual PSI values is classified according to the method proposed by (McKee et al,1993) (figure 11).

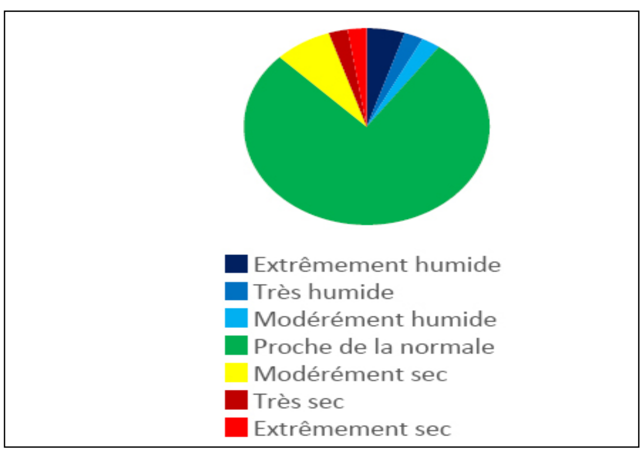


Figure 8. Percentage frequencies of the annual PSI in the study area (1981-2020).

- The percentage of having an extremely wet period is low with a rate of 7.5%.
- The percentage of having a very wet period is low with a rate of 2.5 %.
- The percentage of occurrence of a near-normal period is very high equal to 77.5 %.
- The percentage of occurrence of a moderately and severely dry period is also low (estimated by 7.5 %).

- The percentage of occurrence of a moderately wet period is low during the whole study period (1981-2020, 2.5 %).
- The percentage occurrence of an extremely dry period is also low (2.5%).

Seasonal Scale

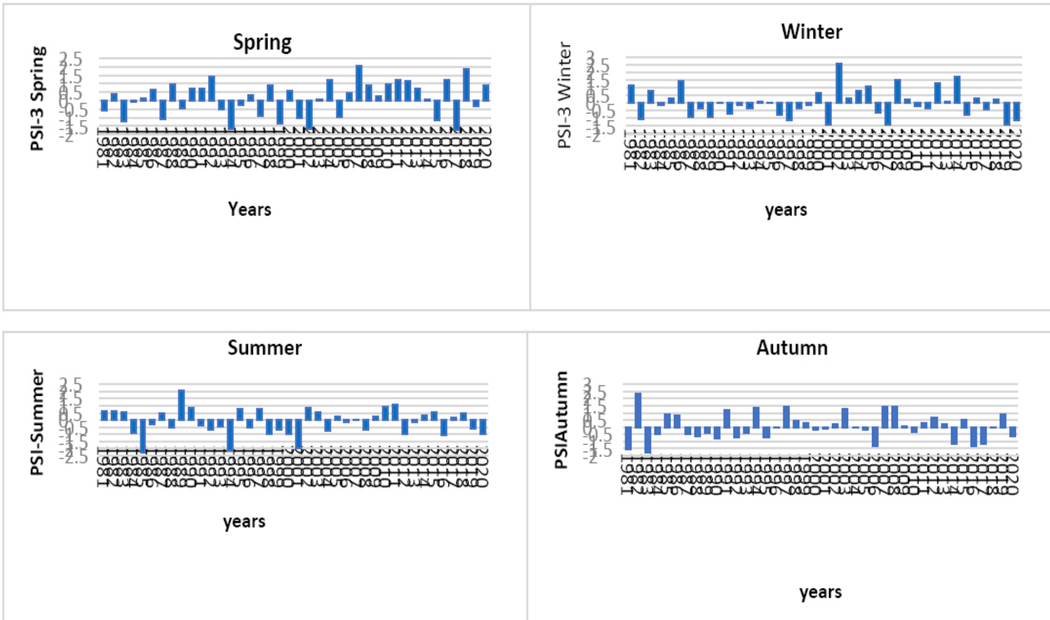


Figure 9. Evolution de l'intensité de la sécheresse (ISP, d'Automne) dans la région sur la période d'étude (1981-2020).

The graph shows the seasonal index (PSI), noting the annual alternation visualized in Figure 12. We also noticed that the highest seasonal index is the wettest year, and the seasonal index of the years 1993 and 2001 confirms that these are the least rainy years.

- **Spring**

Evolution of drought intensity (PSI, Spring) in the region over the study period (1981-2020).

- 8 years are characterized by a slightly dry period, with a PSI interval of 0 to -0.99, with a probability of occurrence of once every 3 years.
- 05 years (1983, 1987, 1999, 2001, and 2015) which are characterized by a moderate drought with a PSI between -1 to -1.49, this drought category has a probability of occurrence of once every 10 years.
- 03 years (1994,2002, 2017) which are characterized by a very dry drought with a PSI interval of -1.5 to -1.99 at a probability of occurrence of 1 time every 20 years.
- In all 40 years of winters the region does not experience any period of severe or extreme drought.

- **Winter**

Evolution of drought intensity (PSI, Winter) in the region over the study period (1981-2020).

According to Figure 14, we note that:

- 15 years are characterized by a slightly dry period more remarkable, by a PSI interval of 0 to -0.99, with a probability of occurrence of only once every 3 years.
- 05 years (1982, 1997, 2001, 2007, and 2019) which are characterized by a moderate drought with a PSI between -1 to -1.49, this drought category has a probability of occurrence of once every 10 years.
- In all 40-year winters the region does not experience any period of very or extremely dry weather.

- **Summer**

During the period 1981 – 2020, the summer season was characterized by:

- years with a mild drought (PSI between 0 and -0.99), so it may return once every 3 years.
- Only three years of moderate drought, in 1998, 2000, and 2016 with a PSI of -1.014, -1.011, -1.028, where the probability of occurrence is 10 out of 100 years, so it can return once every 10 years.

- The year 2001 is a very dry summer, with a PSI= -1.64 and a probability of occurrence of once in 20 years.
- The years 1984, 1994 are extremely dry years with a PSI of -2.237 and - 2.150 and a probability of occurrence of once in 100 years.

- **Autumn**

- A predominance of normal autumn, 16 normal autumns over 40 years, a period characterized by a mild drought in the following years (1984, 1987/1996, 2000, 2001, 2004,2005,2010, 2018, 2020), with a PSI between (0 and - 0.99), then it can be said that the region can be exposed to a mild drought with a frequency of once every 3 years.
- For the years 2006, 2014, 2016, and 2017, the results show a moderate drought characterized by a PSI between -1 and -1.49, so it can be said that the region may be exposed to a once in 10 years drought.
- Two years (1981-1983) characterized by a severe drought, PSI equal to -1.52 and -1.775 with a probability of occurrence 05 times in 100 years.
- During the 40 years studied the BBA region was never exposed to extreme drought.

Correlation between SPI and SVI

At this stage of the research, we have studied the correlation between PSI and SVI over 20 years, from 2000 to 2020, using SPI-6 and SVI to explore agricultural drought, and SPI-3 and SVI for Hydrological Drought, SPI-12, and SVI for the socio-economic study of drought. Correlation between SPI-6 and SVI

Table 6. Represents the values of SPI-6 and SVI in June and December. (2000-2020)

YEARS	SPI-6	SVI	YEARS	SPI-6	SVI	YEARS	SPI-6	SVI	YEARS	SPI-6	SVI
Jun 1, 2000	-0.966	-0.922	Dec 1, 2000	-0.422	-0.9265	Jun 1, 2010	-0.058	-0.0705	Dec 1, 2010	0.891	0.1305
Jun 1, 2001	-0.69	-0.7455	Dec 1, 2001	-2.308	-0.9255	Jun 1, 2011	0.561	0.455	Dec 1, 2011	0.834	0.3285
Jun 1, 2002	0.426	-1.5805	Dec 1, 2002	1.757	-1.324	Jun 1, 2012	-0.434	0.02025	Dec 1, 2012	1.419	0.5345
Jun 1, 2003	1.457	0.1605	Dec 1, 2003	1.277	0.236	Jun 1, 2013	0.163	0.9735	Dec 1, 2013	0.081	-0.1005
Jun 1, 2004	-0.658	0.98	Dec 1, 2004	-0.264	-0.242	Jun 1, 2014	-1.075	0.0025	Dec 1, 2014	0.196	-0.2525
Jun 1, 2005	-0.115	-0.1655	Dec 1, 2005	1.061	0.2775	Jun 1, 2015	0.68	0.0005	Dec 1, 2015	0.589	0.863
Jun 1, 2006	-1.352	-0.16	Dec 1, 2006	1.301	-0.1085	Jun 1, 2016	-1.733	-0.6215	Dec 1, 2016	-1.256	-0.537
Jun 1, 2007	1.456	0.815	Dec 1, 2007	-0.112	0.905	Jun 1, 2017	-1.116	-0.8695	Dec 1, 2017	1.255	-0.844
Jun 1, 2008	0.267	-0.263	Dec 1, 2008	1.211	0.806	Jun 1, 2018	0.093	1.171	Dec 1, 2018	-0.146	0.675
Jun 1, 2009	0.084	1.1655	Dec 1, 2009	0.929	0.2275	Jun 1, 2019	0.717	0.3245	Dec 1, 2019	-0.073	0.8785

Interpretation

- Based on the study of the statistical relationship between the SPI on a six-month scale and the SVI for the region during the period 2000 - 2020. The results, as in Table (06), indicate a positive relationship in the correlation between rainfall and the SVI, which shows that there is an estimated correlation of $R^2 = 0.138$, and for information, this study included the average of the region as a whole, so there are other factors affecting the strength of the correlation, but in general there is a high agreement between the two indicators between most points in the study area.
- The year 2001 is considered the driest year in terms of the value of the IPS and IVS, particularly the value for the second half of the same year, as it was estimated to be less than -2 for the IPS and -0.92 for the IVS.

- Noting also that the first and second half of 2016 showed a strong agreement between the two indicators. The IPS value for the same year was estimated to be -1.7, the IVS value was -0.62 for the first half of the year, the IPS was -1.25 and the IVS value was -0.53. It indicates very severe dehydration.

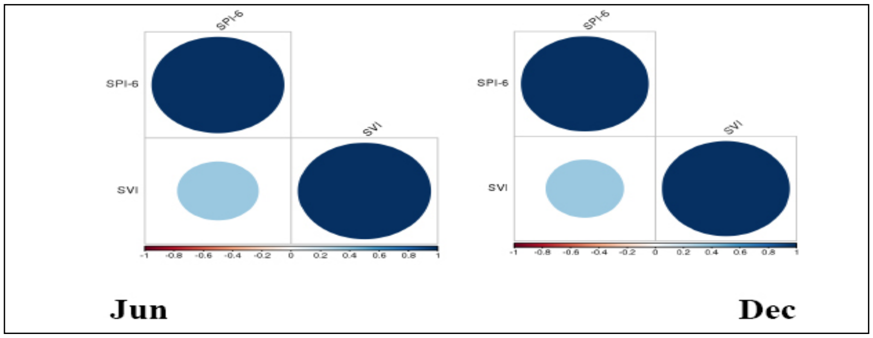


Figure 10. Correlation coefficient and linear equation between SPI-6 and SVI (2000-2020).

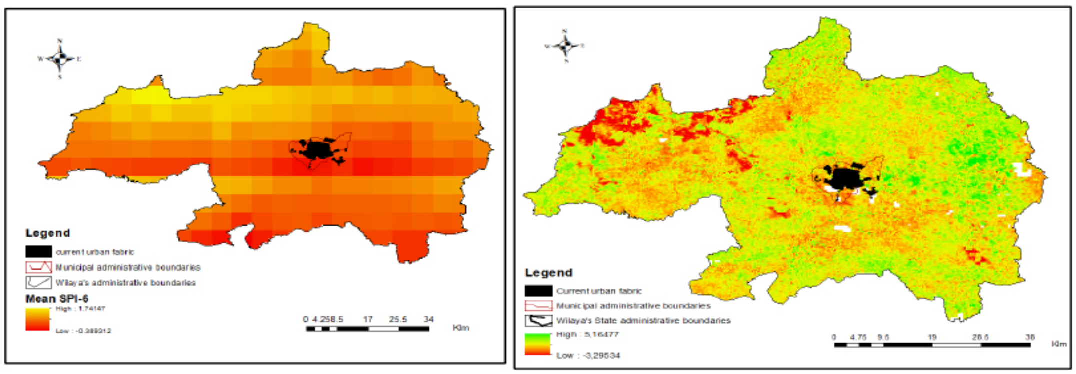


Figure 11. Comparison of average SPI-6 and SVI over the period 2000-2020

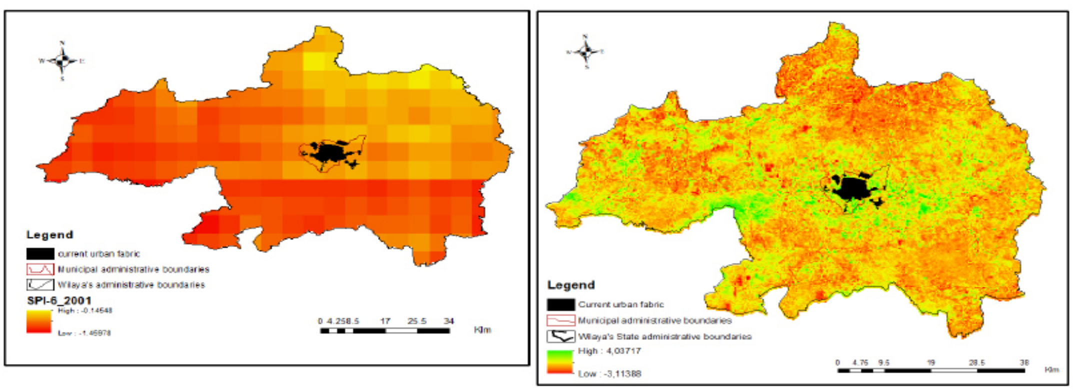


Figure 12. Comparison of the driest year for the SPI-3 and SVI indicators for 2001 (2000-2020).

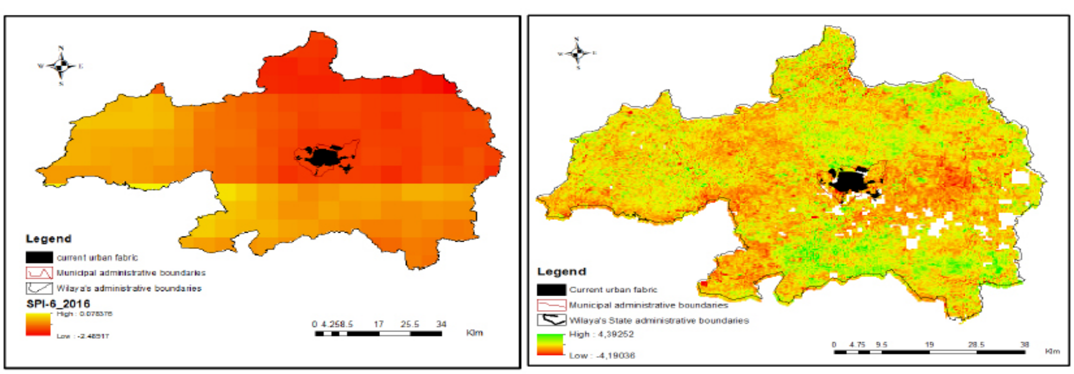


Figure 13. Comparison of the driest year for the SPI-3 and SVI indicators for 2016 (2000-2020).

Correlation Between SPI-3 and SVI

Interpretation

The results, as in Tables (07) and (08), indicate a positive relationship in the correlation between precipitation and the S VI index, which shows that there is an estimated correlation of R^2 = 0.104, R^2 = 0.0541, R^2, R^2 = 0.0806, R^2 = 0.2217, for January, October, July, April respectively, and for the same reason, this study included the average of the whole region, so there are other factors affecting the strength of the correlation (temperature, soil moisture, topography of the region), but in general, there is a high degree of agreement between the two indicators between most points in the study area. Noting that the spring of 2001 was a severe drought with a value of -1.7 for SPI3, which corresponds to the value of SVI, which was estimated at -1.63.

Table 7. SVI values in October, January, April and July. (2000-2020)

	Oct	Jan	Apr	Jul		Oct	Jan	Apr	Jul
2000	-0.074	-1.263	0.336	-0.734	**2011**	0.712	0.353	1.717	-0.759
2001	-1.237	-0.295	-0.933	0.556	**2012**	0.834	0.236	0.686	-1.123
2002	1.287	-1.173	-1.765	-0.05	**2013**	0.313	1.898	0.032	0.389
2003	2.098	1.351	0.672	0.483	**2014**	-0.227	1.039	-0.626	-1.217
2004	1.151	-0.351	1.546	-0.997	**2015**	-0.284	1.057	-1.387	0.413
2005	0.162	-0.376	-0.568	-0.287	**2016**	-0.859	0.477	0.703	-1.42
2006	-1.394	0.041	1.07	0.259	**2017**	-0.466	-0.55	-0.917	-1.351
2007	-0.379	0.744	1.149	1.905	**2018**	-0.563	0.314	1.545	-0.308
2008	1.017	-0.889	0.814	0.026	**2019**	0.107	0.648	-0.639	1.304
2009	-0.967	1.203	0.094	2.048	**2020**	-0.433	-0.449	0.136	-1.145
2010	-0.082	0.671	0.859	-1.104	**2011**	0.712	0.353	1.717	-0.759

Table 8. SVI values in October, January, April and July. (2000-2020)

	Oct	Jan	Apr	Jul		Oct	Jan	Apr	Jul
2000	-1.012	-0.8456	-1.0695	-1.022	2011	-0.056	0.354	0.377	0.2845
2001	-0.574	-0.9745	-0.828	-1.0855	2012	-0.0785	0.3145	0.2585	0.246
2002	-1.368	-1.231	-1.6315	-1.596	2013	0.091	0.4935	0.856	0.9295
2003	-1.368	-1.136	-0.2375	0.0835	2014	-0.431	0.12	0.295	-0.0105
2004	0.393	0.138	0.509	1.007	2015	1.01	-0.385	0.2215	-0.0055
2005	0.243	-0.4745	-0.0695	-0.559	2016	-0.8005	0.482	0.098	-0.2995
2006	0.166	0.273	0.018	0.223	2017	-0.593	-0.602	-0.89	-0.704
2007	1.453	-0.303	0.7545	0.643	2018	0.535	-0.5665	0.378	0.774
2008	1.145	0.5015	-0.3425	-0.1325	2019	0.668	0.8435	0.5115	0.488
2009	0.43	1.035	0.9125	0.955	2020	0.7588	0.8725	0.4435	0.182
2010	0.017	0.3505	0.2785	0.0235	2011	-0.056	0.354	0.377	0.2845

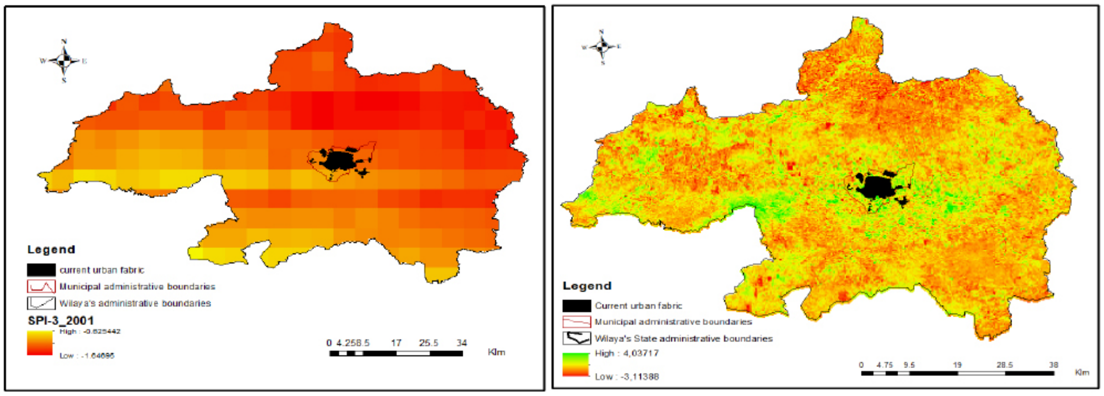


Figure 14. Comparison of driest year for SPI-3 and SVI indicators for 2001 (2000-2020).

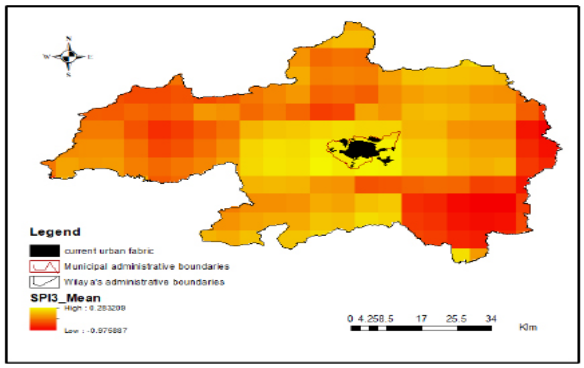


Figure 15. Average SPI-3 for the period 2000-2020

Correlation Between SPI-12 and SVI

Table 9. SPI-12 and SVI values, period (2000-2020).

Years	SPI	SVI	EVI	Pr	Years	SPI	SVI	EVI	Pr
2000	0.324	-1.05	0.179	361.839	2011	1.717	0.305	0.244	423.969
2001	-0.933	-0.826	0.189	290.319	2012	0.673	0.023	0.232	480.223
2002	-1.765	-1.592	0.148	510.836	2013	0.032	0.595	0.257	439.588
2003	0.672	-0.51	0.206	497.544	2014	-0.626	0.609	0.258	372.96
2004	1.532	0.427	0.251	401.302	2015	-1.387	0.391	0.245	428.046
2005	-0.568	-0.174	0.214	442.214	2016	0.689	0.275	0.249	306.012
2006	1.07	0.142	0.233	426.984	2017	-0.917	-0.667	0.188	428.304
2007	1.149	0.445	0.204	408.811	2018	1.545	0.342	0.257	386.488
2008	0.801	-0.283	0.216	507.699	2019	-0.639	0.57	0.257	402.934
2009	0.094	0.837	0.265	468.457	2020	0.124	0.567	0.259	391.672
2010	0.859	0.25	0.242	451.345	2011	1.717	0.305	0.244	423.969

Interpretation

- The results, as in Table (09), indicate a positive relationship in the correlation between SPI and SVI, which shows that there is an estimated correlation of R^2 = 0.149, which is for the period 2000 - 2020 and the average of the whole region, and also, in general, we find a high agreement between the two indicators between most of the points in the study area.
- Noting that the period 2002 showed a strong agreement between the two indicators, the SPI value for the same year was estimated at -1.7, and the SVI value at -1.5, reflecting a very severe drought.

- Figure N°17 shows a weak correlation between rainfall and the EVI, SVI, and SPI, and a positive correlation between EVI and SPI. This result can be explained by the fact that the area we studied is not climatically harmonious, but the predominant climate is dry and semi-arid (the steppes region), which affects the strength of the correlation between the indicators

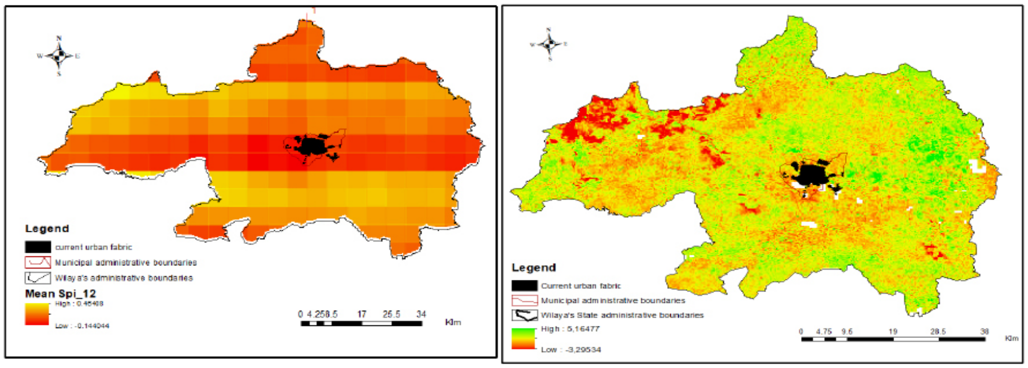


Figure 16. Comparison of the driest year for the SPI-12 and SVI indicators for 2002 (2000-2020).

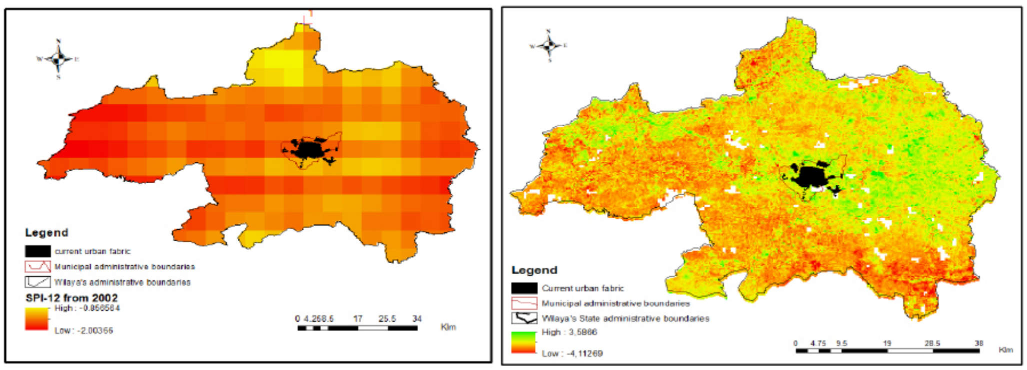


Figure 17. Comparaison de l'année la plus sèche pour les indicateurs SPI-12 et SVI pour 2002 (2000-2020).

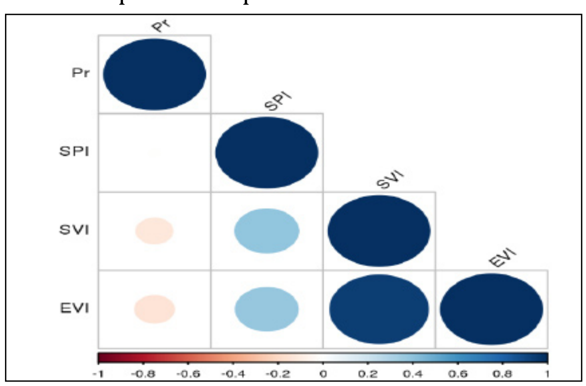


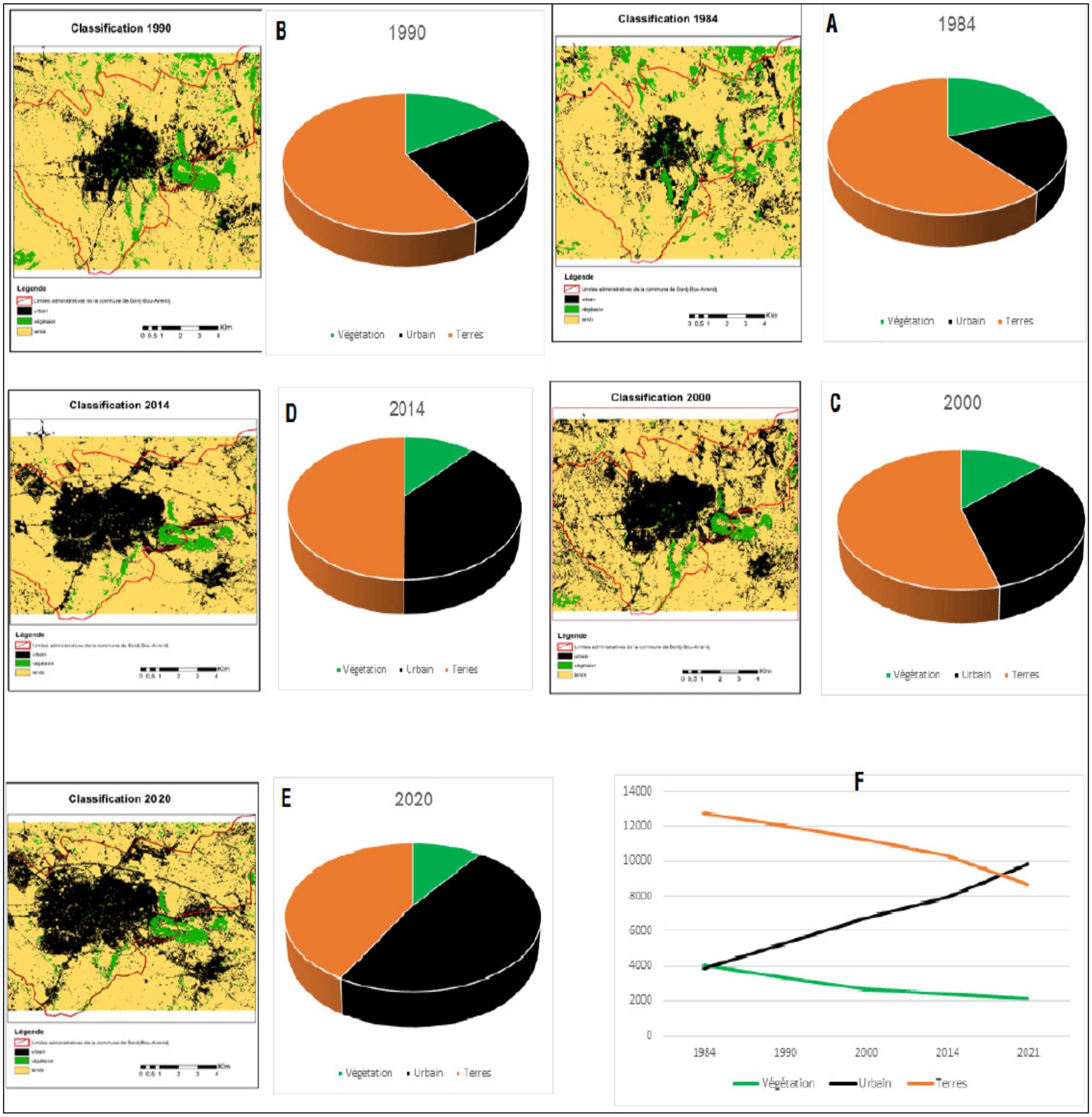
Figure 18. Coefficient de corrélation et équation linéaire entre SPI-12, SVI, EVI et Pr (2000-2020).

Land-Use Change

All results are summarized in Table 10, Graph 01, Figure 05, A, B, C, D, and E which includes all periods studied:

Table 10. La superficie de chaque classe qui convient à chaque année

Classes (Ha)	1984		1990		2000		2014		2021	
Végétation	4043,48	19.6	3286,35	15. 93	2659,20	12.89	2384,82	11.56	2137.26	10.36
Urbain	3837,18	18.6	5287,46	25.63	6766,64	32.80	7942,55	38.50	9861.14	47.80
Terres	12749,34	61.8	12056,17	58.44	11204,15	54.31	10302,62	49.94	8631.59	41.84
Totale	20630	100	20630	100	20630	100	20630	100	20630	100



Graph

Interpretation

- Referring to the result (Fig. 05, classifications from 1984 to 2020 and graph for each period) classification gain for 36 years, it can be seen that the vegetation cover species show a relatively decreasing trend. All vegetation types showed a decrease, especially between 1984 and 1990 (19.6, 15.93, 12.89, 11.56, 10.36%) with an area of (4043.48, 3286.359, 2659.207, 2384.828, 2137.26 ha).
- The urban fabric: it can be seen from the previous maps that it has doubled over the 36 years studied, but the rate of development is constant between the different periods, except the period between 2014 and 2020. This is the most important in terms of the surface area of the built-up area, as it went beyond the administrative boundaries of the municipality and the beginning of its integration into the rural areas surrounding the agglomeration.

- As for the land, as mentioned earlier, most of it is agricultural land, and the cultivation of cereals is the most important, but due to recurrent periods of drought, the lack of its yields, and the increase in demographic pressure, the main cause of which is a large migration of the population from neighboring regions and from outside the state, Forcing its owners to change their activities from agricultural to commercial and industrial activities on the one hand, and on the other hand, the high price of real estate compared to agricultural real estate.

CONCLUSION

The main results obtained show that above-average and below-average periods alternate. This alternation is related to its duration and irregularity.

From a climatic point of view, the study area is characterized by a Mediterranean climate and is in a semi-arid and arid bioclimatic stage, with hot, dry summers and more or less harsh winters. The maximum rainfall is 551.4 mm, and the minimum rainfall is 214.2 mm. Over the 40 years from 1981 to 2020, the PSI index has been calculated as follows:

- The results showed at the annual level that drought is caused by the frequency of several consecutive years and repeated over several years, which leads to stress on the vegetation cover and the stock of agricultural land of humidity and runoff of water and soils. underground waters.
- Allows for the detection of dry and wet periods. The results obtained indicate that the Bordj Bou Arreridj area is a semi-arid zone. The latter has experienced climate change over the last 20 years.
- According to the PSI, the dry season extends over the same period (1998 to 2002), and more than half of the sequence features close to the normal period (60%) and the remaining period of (40%) is also calculated between the dry and wet seasons. The seasonal indicators show the annual changes visualized by the rainfall. It can also be seen that the intensity of the drought episodes is concentrated in the summer period, then in autumn, and finally in winter and spring. Given the results obtained, the rationalization of water consumption is of great importance, especially in the case of the population and water for agriculture.
- By studying the correlation between the SVI and SPI indicators, it showed a positive correlation, especially the threshold values that express severe dehydration, at all monthly levels, 3 months, 6 months, and 12 months.

The importance of the study lies in the analysis of droughts of all kinds, especially social and economic droughts, where this phenomenon represents a vital element because it is linked to water resources, programming, and management, especially in the agricultural aspect, especially with a significant decrease in rainfall in recent years and the largest source of water that depends The area is the Ain Zada Dam, which is located on the borders of the states of Setif and Bordj Bou Arreridj, which is known for its low quantity, and water sources are among the problems that are considered a challenge and have great weight in development projects in the region at all levels. The social and economic transformations that the region has undergone express the response of the urban system to the phenomenon of drought, and this is due to the development plans under the auspices of the state by making the region an economic pole for the regional budget, but with that the challenge remains on the table, and it is necessary to search for new sources that keep pace with future aspirations.

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