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# The use of remote sensing and Geographic Information Systems in Monitoring drought the Algerian steppe

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**Abstract**. The present study aims to use remote sensing techniques and geographic information systems (GIS) in monitoring and detecting droughts in the steppe regions (Tiaret city as a model) during the period (2002-2022). In pursuit of this aim, some indicators were used, such as the surface temperature index (LST), soil moisture index (SMI), standardized difference vegetation index (NDVI), and aridity index (AI). Depending on the Terra satellite's visuals, which are specialized in observing the earth and tracking changes that may occur in it. The purpose of the study is to demonstrate the extent to which the Algerian steppe regions, particularly the southern ones, are vulnerable to drought as a result of the climatic changes that the globe is experiencing in general. This is confirmed by the indicators that were used in this study (LST), (SMI), ( NDVI), (and AI), In addition to this, unregulated activities, such as grazing, unplanned reclamation, and others, have exacerbated the severity of the problem, and in order to safeguard this environment, it must be regularly monitored and protected.

**Keywords**. drought indicators, geographic information systems, remote sensing, the Algerian steppes (Tiaret)

## 1. Introduction

The world undergoes severe droughts from time to time, the impact of which varies depending on the severity and extent of the fragility of the natural environment, as well as its ability to resist biological degradation that may affect the land as a result of climate change on the one hand, and irrational exploitation of the natural resources of the environment in which it is active on the other. in contrast, a human being. The state of Tiaret is one of the steppe states in Algeria and is characterized by the fragility of its environmental environment, which makes it vulnerable to climatic changes and unstudied activities, that result in the shrinking of grassy areas, including the creation of a semi-desert environment, especially in its south bordering the desert.

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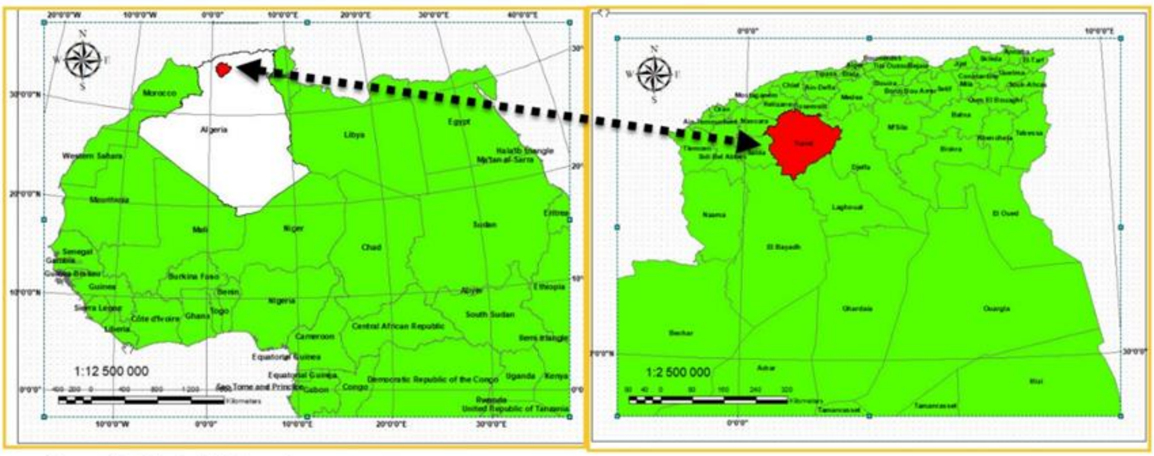
**Statement of the problem**

Drought is a worldwide occurrence that has differing degrees of impact on different environmental circles. The extent of this impact grows if the phenomenon occurs repeatedly at closely spaced times in one particular geographic area. Algeria goes through droughts from time to time, which greatly affect its fragile regions, especially the steppe regions, which are considered the gateway to the desert. Therefore, specialists must track and monitor this phenomenon in order to provide appropriate protection for it as soon as possible, with the help of modern technologies in this field, such as remote sensing and computerized geographic information systems.

## 2. Research tools and methods

### 2.1. Study Location

**Map No. 1: The location of the city of Tiaret**




**Prepared by:Khenioui Abderrezak**

This study is conducted in the city of Tiaret, which is located in the northwest of Algeria and is bordered on the east by the state of Djelfa, on the north by the states of Tissemsilt and Relizane, on the northwest by Mascara, on the west by Saida, on the southwest by El Beidh, and on the southeast by the state of Laghouat. Astronomically, it is located between longitudes (2°40'9" and 0°29'1") east, and two latitudes (35°42'50" and 34°4'34") north, (see map 01).

The state of Tiaret includes 42 municipalities with an estimated total area of 20,673 km2. The region is characterized by the variation and diversity of its topography, although it is dominated by a steppe character. The following table 1, summarizes the natural characteristics of the city of Tiaret.

**Table 1. Summarizes the natural characteristics of the city of Tiaret..**

| Terrain | | Slopes | |
|---|---|---|---|
| **Medium height** | 965 m | **Average Slope** | 4.93° |
| **Highest height** | 1507 CE | **Maximum slope** | 56.08° |
| **Lowest height** | 262 m | **Lowest slope** | 0° |

Source: Prepared by the researcher using Arc Gis on Dem

### 2.2. Data used in the study

There are many variables that directly or indirectly affect drought in a specific geographical area, and the nature of the tools used in this study (remote sensing and geographic information systems) requires reliance on many data from different sources, including what is in the form of satellite images of all kinds (electro-optical / radar), as well as what is in the form of field statistical data. Each of these pieces of data has its own advantages and characteristics that are unique to it, as well as its own uses. Therefore, the following has been used:

- Sentinel-2, a European Earth-imaging satellite with a 10-meter spatial resolution and the second of the Sentinel generation, was launched by the European Space Agency on March 7, 2017, as part of the Copernicus space program. This satellite is distinguished by its scientific equipment used to scan a large area of the earth so that the images are of high resolution due to the multi-spectral imaging that contains 13 spectral bands.
- Digital elevation data (DEM) with a spatial accuracy estimated at 30 m. It is free data that was collected with the intention of automatically extracting a variety of significant information, including topographical information such as the nature of the terrain, inclinations, slopes, basin borders, waterways, and valleys, as well as other information. The data were downloaded from the following website: https://earthexplorer.usgs.gov/
- Satellite visuals of the (Terra) satellite of the American space agency NASA, which carries five remote sensing probes on board, including (MODIS), whose visuals were used in this study. This satellite was sent for the purpose of scientific studies related to changes that occur on the surface of the earth, seas, and oceans alongside.
- High-resolution global climate data (30 arc seconds) for the period 1970-2000 related to evaporation, transpiration, precipitation deficit, etc., in point layer format downloaded from the following website:
https://cgiarcsi.community/data/global-aridity-and-pet-database

### 3. Research methodology

This study employs an analytical-descriptive approach, gathering information and data that have a direct or indirect impact on the drought in the state of Tiaret and connecting the relationship between these factors to arrive at the results via these evidence and clues:

- Using the (ARC GIS) program in processing satellite visuals and the digital elevation model, including correcting, classifying, and merging the visuals, calculating indicators specialized in tracking vegetation, monitoring drought, and outputting information in the form of maps and tables in their final form,
- Extracting the land use map of the state of Tiaret for the year 2021 AD through the world map of land use produced by three companies, namely, Esri, Impact Observatory, and Microsoft, using satellite images (Sentinel-2) with a spatial resolution of 10 meters, revealed seven land uses in the state of Tiaret that vary in terms of area and distribution (see map 02).
- Studying the seasonal change of the Earth's surface temperature during the four seasons (autumn, winter, spring, and summer) and for the last three years, i.e. from (2020 to 2022 AD) using 12 visuals of the Terra satellite through the remote sensing probe (MODIS) and loaded from the site ( https://earthexplorer.usgs.gov/) They are visuals with an average spatial resolution of 1 km, but they have a large temporal resolution, as they are updated daily, knowing that the visuals used in this study are ready for direct use, meaning that they have been applied to equations that extract the Earth's surface temperature in Kelvin (LST) by the

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company that owns it, and since we use the Celsius temperature in our region, we convert its values to Celsius.

- Calculating the soil moisture index for the state of Tiaret during the last three years (2020-2021-2022) and in the four seasons, the current research is carried out in two stages:
  - **The first stage.** preparing the visualizations used in the study of the seasonal change in the surface temperature of the Earth (LST).
  - **The second stage**. calculating the soil moisture index (SMI) using a mathematical equation using the ArcGIS program, based on the (MOIS) visualisations that show the land surface temperatures (LST) according to the following equation:

**SMI = (LSTmax – LST) / (LSTmax – LSTmin)**

**Where**
**SMI**: Soil Moisture Index
**LST:** Land Surface Temperature
**LSTmin/max**: Max & Min values of Land Surface Temperature

- Using satellite imagery from the Modis-Terra satellite, which is regarded as one of the most significant satellites that aim to monitor the Earth and study Changes that may occur in various environmental fields, we studied the temporal change of vegetation cover in the state of Tiaret from the year 2002 AD to 2022 AD. This was done depending on the standard difference index of vegetation cover (NDVI) in different seasons.

There are many indicators that are used to detect and monitor the vegetation cover using remote sensing techniques, perhaps the most prominent of which is the Standard Difference Vegetation Cover Index (NDVI).

The value of this indicator is calculated through the following equation:

**NDVI = NIR-RED/ NIR+RED**

**Where.**
**NIR**: near-infrared reflection spectrum.
**RED**: reflectance range of the infrared spectrum.

- Extracting the aridity index for the state of Tiaret from the global climate, evaporation and transpiration database, which uses the following equation:

**Aridity index=MAP/MAE**

**Where**.
**MAP**: Mean Annual Precipitation
**MAE**: Mean Annual Pentagonal Evaporation – Transpiration

## 4. Results and discussion.

### 4.1. Land usage.

The objective of knowing the land uses of the state of Tiaret is to highlight the shape of the biophysical cover that was monitored for the study area at that time (2021) in order to realize and understand the changes that occurred and may occur on the ground as a result of human intervention on the one hand and the continuous environmental changes on the other (see Map No. 02). Thus, it is an important means by which the necessary measures can be taken, such as limiting activities that may lead to damage to lands, especially agricultural ones, and through them it is also possible to discover the correct way to preserve and protect those lands as much as possible.

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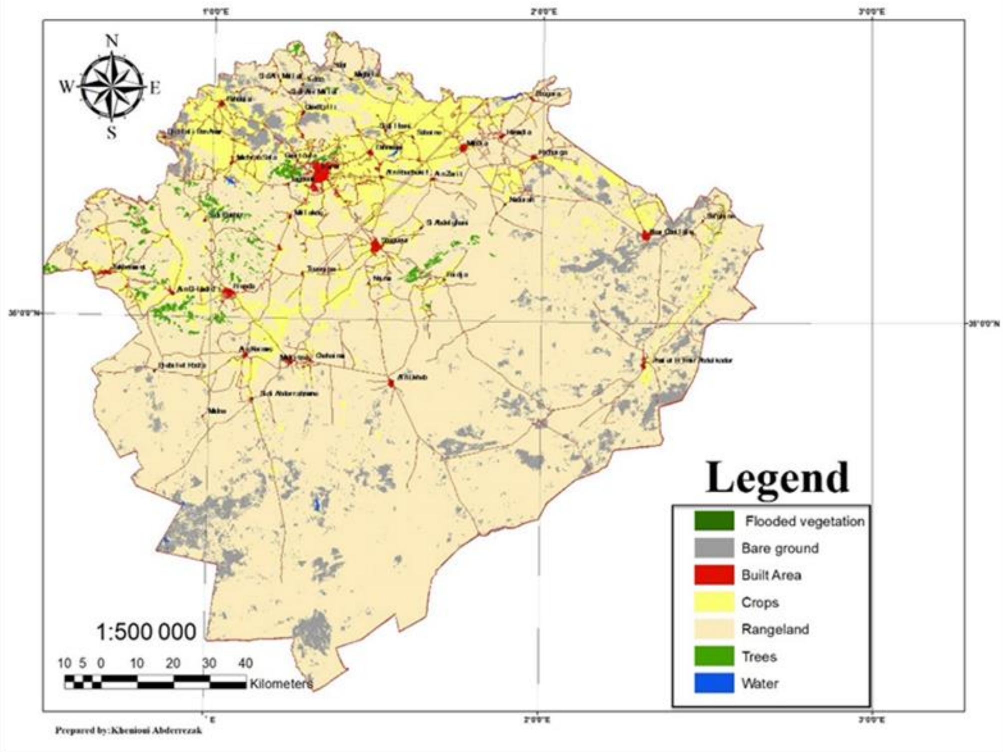
Map no.2:Land use maps of Tiaret2021




Based on the land use map of Tiaret produced using the ArcGIS program, the areas and proportions of each land cover can be extracted in order to facilitate the process of analyzing the obtained results. (See table 2 for land usage in Tiaret in 2021).

**Table 2. Land Uses for Tiaret 2021**

| Land Use | Trees | Flooded Vegetation | Water | crops | Built-up area | Rangeland | Bare Ground |
|---|---|---|---|---|---|---|---|
| **Area ($^{km2}$)** | 218,7 | 0,1553 | 13,758 | 2447,75 | 123,2 | 15670,4 | 1635,9 |
| **Percentage %** | 1,087 | 0,0007 | 0,068 | 12.171 | 0,612 | 77.923 | 8,135 |

Source: Prepared by the researcher based on satellite imagery (Sentinel-2)

What can be seen in this map and the table is that most of the area of the city of Tiaret consists of pastoral areas (15,670.4 km2), which is approximately 78% of the general area of the city. This state is adjacent to the desert from the southern side, as it is subject to desertification and sand encroachment, and this is not new in the steppe regions.
If we combine the percentages of pastures, estimated at 77.9%, barren lands, estimated at: 8.13%, and built-up areas, estimated at: 0.612%, the result is approximately 90% of the total area that has the potential to deteriorate, especially if a group of conditions meet, such as excessive exploitation of vegetation cover. On the other hand, the natural characteristics that distinguish these areas, such as wormwood and allies used by livestock breeders, on the one hand, and the drought that alternates in the region from time to time.

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### 4.2. Land Surface Temperature Study (LST)

Four pictures from each of the three most recent research years—2020 AD to 2022 AD—were chosen for the (Modis Terra) satellite and dispersed among the four seasons. The properties of the photos utilized in this investigation are displayed in table 3 below.

**Table3. Dates of visualizations used in the study of the seasonal change in the temperature of the Earth's surface**

| Year | Chapter | Day/Month | Year | Chapter | Day/Month | Year | Chapter | Day/Month |
|---|---|---|---|---|---|---|---|---|
| **2020** | winter | 14 February | **2021** | winter | 29 January | **2022** | winter | 30January |
| | spring | 05 Mar | | spring | 06Apr | | spring | 10 Apr |
| | summer | 24August | | summer | 29August | | summer | 02 August |
| | autumn | 13 Oct | | autumn | 9 October | | autumn | 01 Oct |
| **Spatial resolution** | | 1 km | **Spatial resolution** | | 1 km | **Spatial resolution** | | 1 km |

These visuals were examined and processed using the application (Arc Gis). The outcomes are depicted in Figure 3, which shows the earth's surface temperature for the past three years during each of the four seasons, as well as Table No. 3's description of the earth's surface temperature in the state of Tiaret.

A study of this indicator showed that there has been a significant change in the surface temperature in Tiaret from one month to another, from one season to another, and from one region to another in the last three years. It is known that the steppe regions of Algeria are characterized by a decrease in temperature in the winter and a rise in temperature in the summer, as can be seen from Table. 4 and Map. 3.

**Table 4. Surface temperatures of Tiaret**

| Chapter | Image Date | Surface Temperature (C) | | Thermal range (m) | Average temperature (C) |
|---|---|---|---|---|---|
| | | Minimum | Maximum | | |
| **Winter** | 14-02-2020 | 17.49 | 30.21 | 12.72+ | 23.78 |
| | 29-01-2021 | 13.59 | 28.21 | 14.62+ | 21.71 |
| | 30-01-2022 | 13.03 | 27.07 | 14.04+ | 19.62 |
| **Spring** | 05-03-2020 | 19.71 | 35.93 | 16.22+ | 27.72 |
| | 06-04-2021 | 22.91 | 38.69 | 15.78+ | 29.88 |
| | 10-04-2022 | 21.83 | 40.75 | 18.92+ | 31.14 |
| **Summer** | 24-08-2020 | 39.38 | 55.87 | 16.49+ | 50.47 |
| | 29-08-2021 | 61.87 | 30.81 | 31.06+ | 43.10 |
| | 02-08-2022 | 68.16 | 40.75 | 27.41+ | 50.74 |
| **Autumn** | 13-10-2020 | 39.39 | 24.43 | 14.96+ | 32.05 |
| | 09-10-2021 | 41.66 | 26.99 | 14.67+ | 34.18 |
| | 01-10-2022 | 37.99 | 20.13 | 17.86+ | 27.78 |

Source: Prepared by the researcher based on satellite visualizations (Modis Terra)

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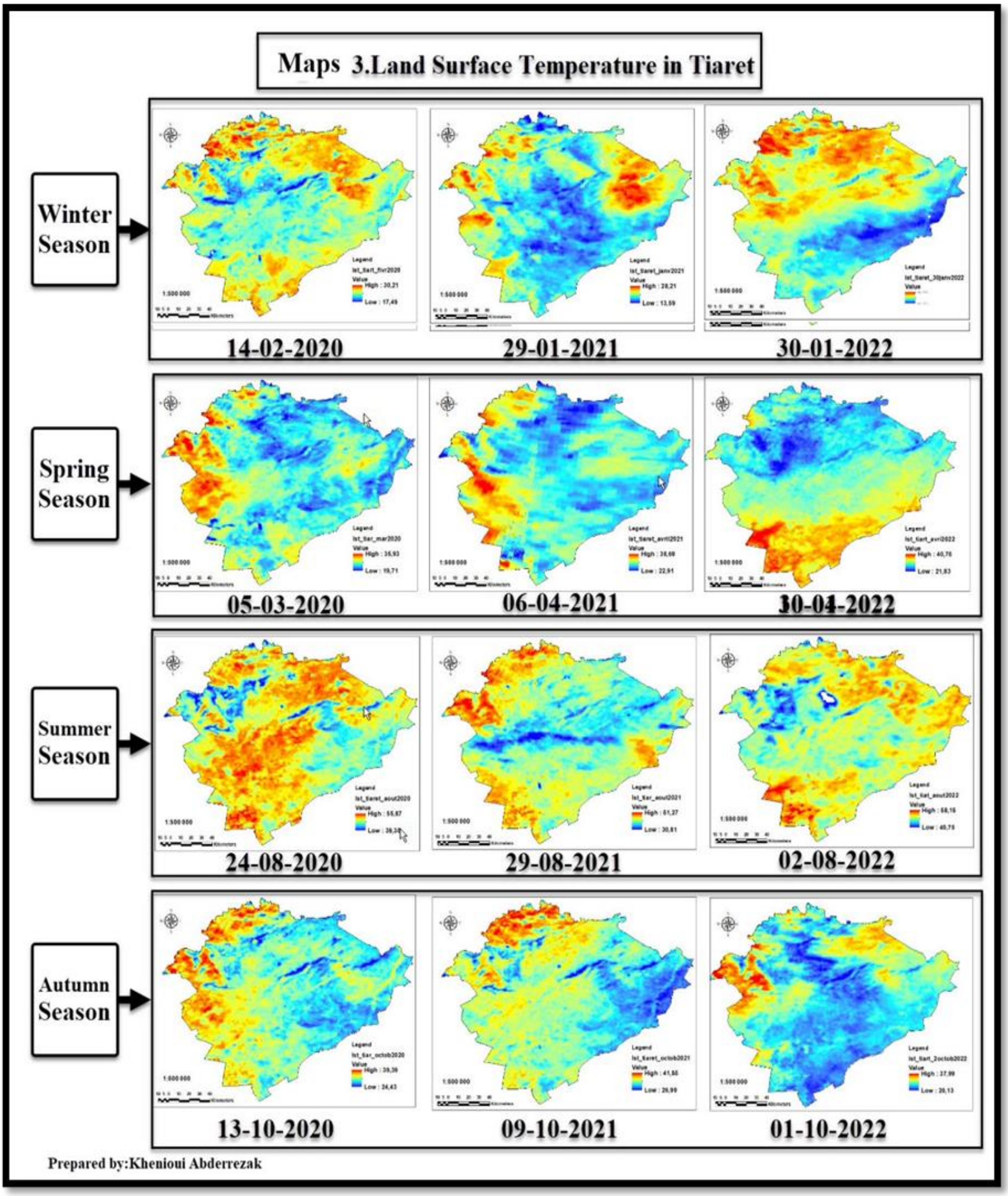


The minimum surface temperature during the winter season for three years (from 2020 to 2022) was no higher than (18 °C), and the maximum surface temperature was no higher than (30 °C), while the average surface temperature ranged between (19-24 °C), with the northern regions of the state of Tiaret experiencing the coldest temperatures. Because the northern regions have the lowest elevations above sea level—less than 750 m—they are hotter, and the influence of altitude may be more significant. Additionally, it was noted that this chapter contained the research area's lowest temperature range, which varied between 12 and 15 meters.

As for the spring, the surface temperature increased for three years (from 2020 to 2022) compared to the winter season, as the average temperature ranged between 27 and 31 C.

As it was discovered that Tiaret's western and southern areas are the hottest, these values varied from region to region. The vegetation that covers the majority of the area during this season is the most significant of the other natural variables that influence this temperature's rise or decline. In the summer, the surface temperature is the highest during the study period for this indicator (from 2020 to 2022), where the average temperature ranges between (43-51 C), and the southern and northern regions experience record-high temperatures compared to the rest of the regions in the state.

This is due to the influence of other natural factors that contributed to the difference in surface temperature, including, for the southern regions, the approach to the desert region and the great heat it experiences in this season, and the disappearance of natural vegetation, especially that which covers pastoral areas in the spring, in addition to the factor of altitude. This season also recorded the highest temperature range compared to all seasons, as it ranged between (16-31 C, which is a large temperature range that will inevitably have an impact on the vegetation cover and soil.

In the autumn season, the average surface temperature fell, ranging between 27 and 32 degrees Celsius. The northern and western regions had the highest surface temperatures in this period of the year, as the region has weak vegetation coverage. This is what makes the soil type Geographical location and altitude are among the factors that affect the surface temperature and its change from one region to another.

We reach the conclusion that there are numerous natural factors that affect the distribution and variation of the surface temperature from one region to another in the state of Tiaret based on the study of the surface temperature in that region using satellite visualizations of the (Modis Terra) satellite. Among these factors is the type of soil, its composition and slope, vegetation cover and its density, climate and its components, altitude above sea level, and proximity to the equator.

Moreover; the interaction of these factors with unstudied human activity for a long time will inevitably leave negative effects on the ecosystem and help the emergence of droughts, and this is what the region suffers from, similar to what the world is witnessing.

### 4.3. Soil Moisture Index (SMI)

Studying the soil moisture index for the city of Tiaret Kahn during the last three years (from 2020 to 2022) and in the four seasons, i.e. the same Modis Terra satellite images of the Earth's surface temperature, was exploited in order to calculate the soil moisture index (SMI) according to the following equation:

$$\mathbf{SMI = (LSTmax - LST) / (LSTmax - LSTmin)}$$

The values of the product of this equation (SMI) range between (1 and 0), values close to (1) represent areas with high humidity such as vegetation and aquatic areas, while values close to (0) represent areas with lower moisture content or suffer from drought; see map 4.

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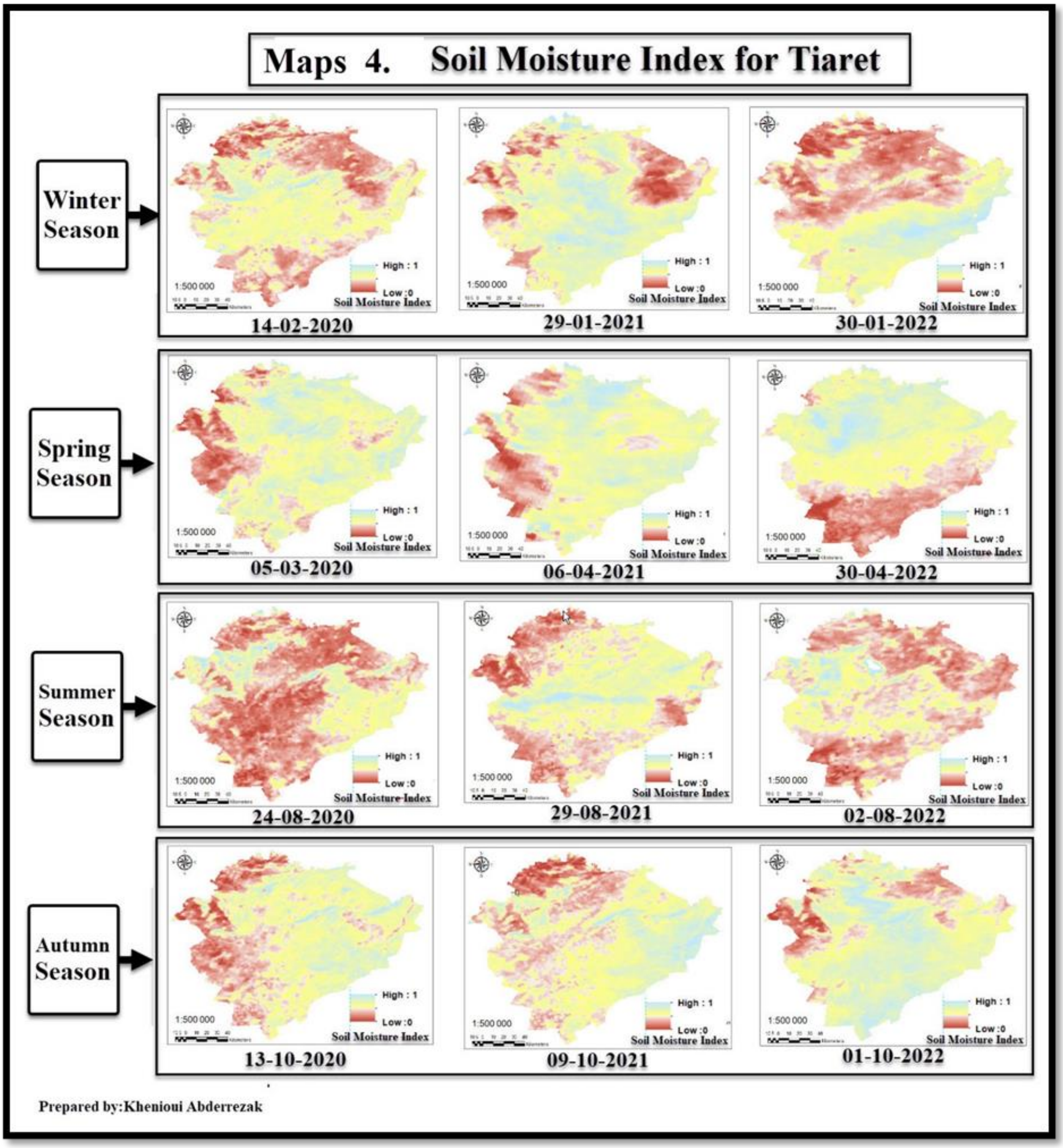


Maps 4. Soil Moisture Index for Tiaret

The study of this indicator showed that there has been a significant change in soil moisture levels in the state of Tiaret from one month to another in the last three years. There are many factors that control the change in soil moisture in the study area from season to season and from one region to another.

The average temperature of the land surface in the state of Tiaret ranges between (19 and 24 C) in the winter months for three years (from 2020 to 2022), and the heaviest precipitation is typically recorded during this time. Most of the areas lack natural vegetation cover of the type of grass that is characteristic of the study area. Due to the flat topography in the southern half of the state, which causes the soil to retain moisture for a longer period of time

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due to a decrease in temperatures, which reduces evaporation in this season, we observe that the southern half of the state experiences more rainfall than the northern half.

As for the spring season, although the average temperature of the earth's surface increased compared to the winter season, it ranges between (27-31 m), but it is noted that there is an increase in the area with moist soil, or even the most humid in the year, due to the moderation of the temperature on the one hand and the spread of natural vegetation cover that On the other hand, it covers the surface of the earth, all of which helps the soil maintain its moisture for a longer period, even if the amount of precipitation decreases.

In the summer, the surface temperature reaches its maximum as the average temperature ranges between 43 and 51 C), and the amounts of precipitation are almost non-existent, which leads to the disappearance of the natural vegetation cover, so the land becomes exposed, the evaporation reaches its maximum, and soil drying occurs.

In the autumn season, the average surface temperature values decline, as they ranged between 27 and 32 C), with the gradual return of precipitation and the beginning of the emergence of vegetation, which helps to increase soil moisture.

By applying the humidity index to the state of Tiaret, we conclude that there are many factors that directly affect soil moisture, including those that cannot be controlled, such as terrain and climate elements, and some that humans can protect and preserve, such as vegetation cover.

### 4.4. Standardized Difference Vegetation Index (NDVI)

The vegetation cover is considered one of the most prominent and important environmental elements through which it is possible to know the natural conditions that characterize a region, especially by monitoring and tracking drought during different periods of time in order to take the necessary measures in the field of agricultural preparation. (15) Modis Terra satellite images were relied upon to monitor the vegetation cover in the state of Tiaret. This series was taken during the last twenty-one years (2002-2022) and distributed over five periods. Three images were chosen from each year, taken over the course of seasons. Summer (Aut), winter (January), spring (April).

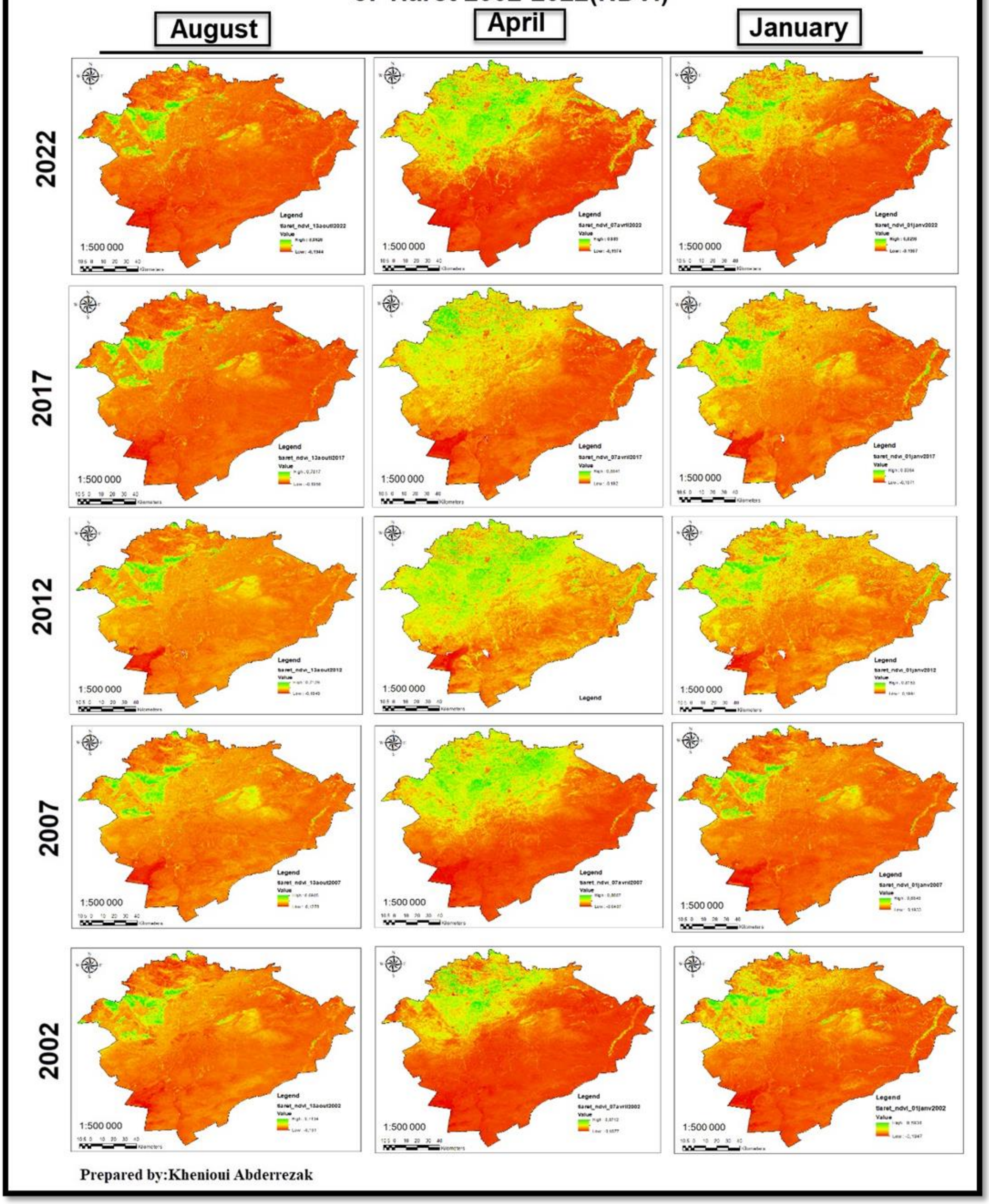
The findings of the equation for this indicator range from (-1 to +1) negative values mainly represent clouds, water, and snow, values close to zero represent bare rocks and soils, and very small values (0.1 or less) correspond to empty areas of rocks, sand, or Snow. Medium values (0.2 to 0.3) represent shrubs and meadows, while large values (0.6 to 0.8) indicate temperate and tropical forests.

Depending on (NDVI), we note that there is a large variation in the density of vegetation cover within the state of Tiaret in general (see map. 5) and this is due to several natural and human factors. The northern region of Tiaret is characterized by the presence of significant vegetation cover in all seasons and over the years of the study period ( 2002-2022), but with an area not exceeding (20%) of the general area, this density decreases as we go south until there is almost no vegetation coverage in the southern regions in all seasons. The spring season is the densest season in terms of vegetation in Tiaret, and this is mainly related to the climate factor, as it is the factor that most controls this indicator. The lowest vegetation coverage, where the vegetation coverage does not exceed (10%) of the public area.

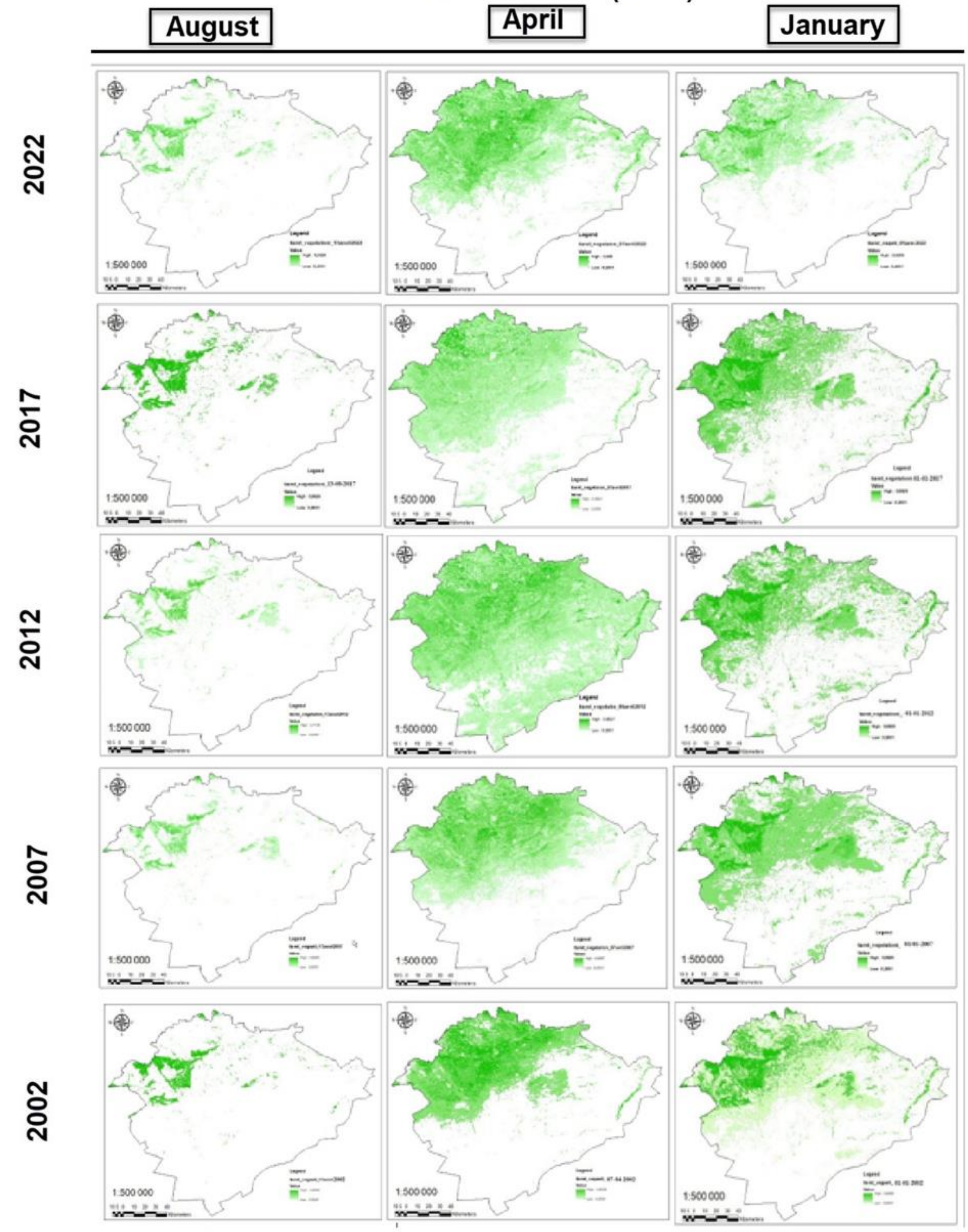
The summer of 2022 was the hottest and driest season, and the vegetation coverage decreased to the maximum extent compared to all seasons and years selected for the study. This confirms the extent of the sensitivity of this medium and its rapid vulnerability to climatic changes that occur in it from time to time.

What is noted from the values of this indicator is that the vegetation cover in all its forms ranges between (0.2 to 1), and to highlight the vegetation cover alone on the map, we isolated the values that range between (-1 to 0.2), so the result highlights the vegetation cover only in order to facilitate the observation process Visual and comparative analysis of images in different chapters and over the duration of the study confirm the findings. (See Maps No. 6)

**Maps.5 Normalized Difference Vegetation Index of Tiaret 2002-2022(NDVI)**



**Maps.6 Normalized Difference Vegetation Index of Tiaret 2002-2022(NDVI)**




Prepared by:Khenioui Abderrezak

### 4.5. Aridity Index (AI)

According to the global aridity index equation mentioned above, which was applied to the state of Tiaret using global climate, evapotranspiration, and transpiration data, and using the (Arc Gis) program, we obtain Map No. From the quantitative results that we obtain, and depending on the classification of the results according to Table 5:

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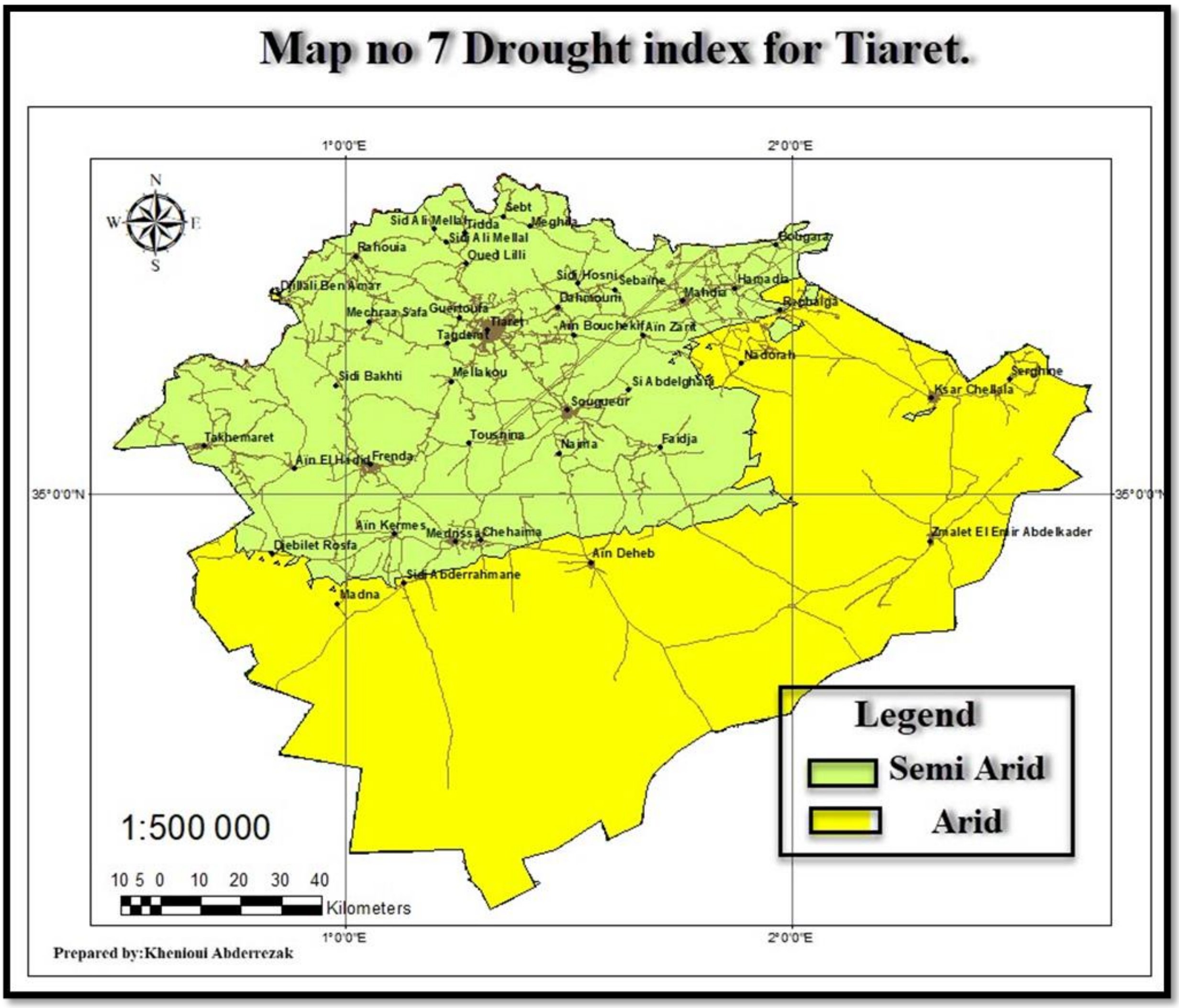
**Table 5. Classification of areas by drought indicator (AI).**

| Climat Class | Value |
|---|---|
| **Hyper-arid** | 0.03 > |
| **Arid** | 0.03-0.2 |
| **Semi-arid** | 0.2-0.5 |
| **Dry Sub Humid** | 0.5-0.65 |
| **Humid** | 0.65 < |




Depending on the answers to the aridity index calculation, Tiaret can be separated into two zones. A dry area, they have an index value between (0.2 to 0.5). These areas are fragile transitional areas that are affected by drought very easily and making them vulnerable to desertification if they are not well monitored and special protection is imposed on them. They have a weak vegetation cover that is primarily made up of holly grasses and wormwood, weak soil thickness, flat terrain, and no natural barriers. Regarding the second semi-arid zone, the aridity index value runs from 0.03 to 0.2, indicating that it is less arid than the southern arid region.

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With a combined area of close to 45% of Tiaret's total land, the northern and western regions are dominant. The interior parts of Algeria, which it borders to the north and has a precipitation rate ranging from 400 to 600 mm per year, are next to this region and are defined by their diverse terrain, which includes mountains and plateaus. Despite its limited amount of flora, it has a variety of grasslands and woodlands. The area has rich, productive soil all throughout it. These qualities enable it. Despite having a higher capacity to withstand drought than its counterpart in the southern half, the region is still impacted by successive dry seasons.

**Conclusions**

The world is currently experiencing significant climatic change, and reports from around the world warn of drought waves, particularly in African nations like Algeria. These waves have an impact on different regions to varying degrees, but because steppe regions are fragile transitional areas between interior and desert regions, their impact is particularly pronounced there. Therefore, authorities and experts must constantly keep an eye on them and, if required, take action to protect them. Even with a broad study region, modern earth science technologies offer highly sophisticated instruments and methods like remote sensing and geographic information systems that make it simpler for researchers to arrive at reliable conclusions quickly.

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