

## RESEARCH ARTICLE

## OPEN ACCESS

## INTEGRATED STRUCTURAL LINEAMENT MAPPING AND GEOTECHNICAL CHARACTERIZATION OF COLLAPSIBLE SOILS IN THE ARID REGION OF BISKRA (ALGERIA)

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## ABSTRACT

Algeria is classified as a semi-arid to arid zone due to the importance of evapotranspiration compared to precipitation. This study presents a summary of experimental results on an unsaturated soil in the Biskra region classified as an arid zone. The behavior of soils in these regions is somewhat unique and evolving. The soils in the Biskra region are distinguished by their geomorphological position and origin, as well as their water regime. They share particular characteristics such as unstable structure often in honeycomb shape, heterogeneity, large porosities, and good surface aeration. It should be noted that the rise of groundwater has continued to shape the urban landscape of the Biskra Valley. The mode of accumulation of soil deposits seems to be mainly responsible for the formation of an open and metastable structure, which is susceptible to collapse. The objective of understanding the effect of lineaments is to be able to better characterize the structure of the soil in this region. The study's primary goal is to locate regions in Biskra region that are prone to soil collapse by combining Remote Sensing and geographical information system (GIS) methods. To create thematic maps such as geology, geomorphology, lineament and lineament density, drainage, drainage density, and slope maps, the researchers employed FCC Image of Landsat TM 30 m resolution data and topographic maps. Several geomorphic units were identified through this process.



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## I. INTRODUCTION

Most soils in arid and semi-arid regions are macroporous with an open and loose structure, existing in the form of metastable deposits. These soils are classified as special problem soils [1]. When dry, clay cementation between the grains provides them with significant intergranular bonding and they can support very heavy loads, exceeding 200 kPa. However, floods and inundations, even without additional loading, induce the breakdown of these bonds, leading to a denser structure followed by a sudden collapse of the soil. The collapse mechanism in partly saturated soil involves the breakdown of intergranular bonds upon wetting [2].

Collapses of macroporous soils are distributed practically all over the earth and are found, essentially, in countries with a dry climate. Several types of collapsible soils have been identified based on their genesis and geological setting [3]. A sudden collapse of the soil can cause other ground movements such as landslides, shearing, planar or rotational sliding, and debris flows. The phenomenon of water transfer in soils in arid zones and its impact on their degradation is a current topic, especially with the trend of investments towards arid and semi-arid areas. The behavior of water in unsaturated soils is complex and requires specific investigation [4]. Experts use geographic information systems (GIS) to organize and examine geographic data by storing it in databases. This technology allows professionals like geographers and engineers to retrieve data from any location on the planet, including those that may be difficult to access through traditional methods. Digital elevation models (DEM) offer a three-dimensional depiction of the earth's surface and are a straightforward method for visualizing the topography of a specific area of study. The methodology followed in this work includes the processing, interpreting of the Landsat 8 satellite images.

## II. BISKRA REGION

### II.1 GEOGRAPHICAL LOCATION AND TOPOGRAPHY OF

The Biskra region covers an area of 21,671.2 km<sup>2</sup> and is situated in northeastern Algeria, sharing borders with the Batna, M'sila, Khenchla, El Oued, and Djelfa region. The region is located at 34°48' North and 05°44' East. The region is considered a transition zone in terms of morphology and bioclimatology, with high and rugged terrain in the north and plateaus and plains in the south. The region can be divided into four main zones, including a mountainous zone in the north with the highest peak being Djebel Takyiout, a plateau zone extending from north to south, a plain zone along the Eloutaya-Sidi Okba-Zeribet El Oued and Doucen axis, and a depression zone in the southeastern part of the region. The region's topography and climate have a significant impact on its development and economy, with agriculture mainly concentrated in the plains and plateaus and forestry and livestock farming more suitable for the mountainous and hilly terrain in the north. Figure 1, 2.

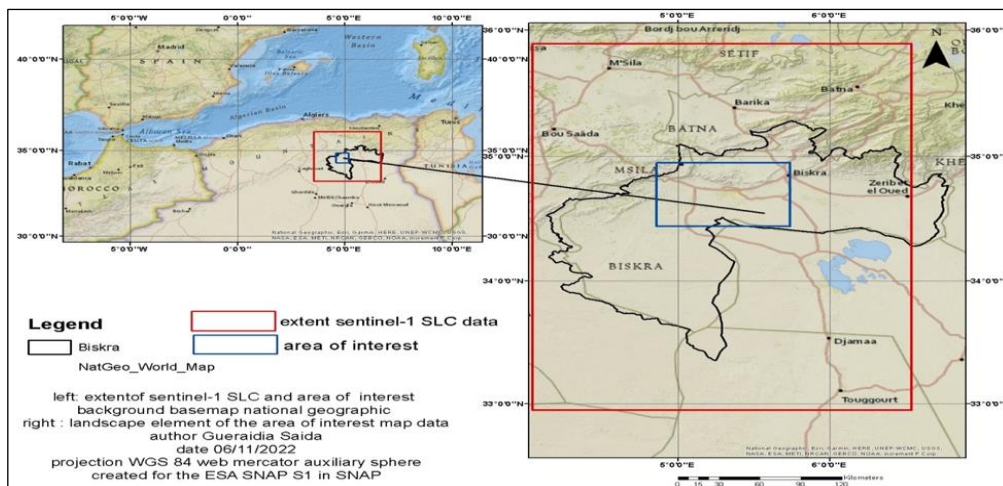


Figure 1: Geographical location of the study area.

Source: Authors, (2026).

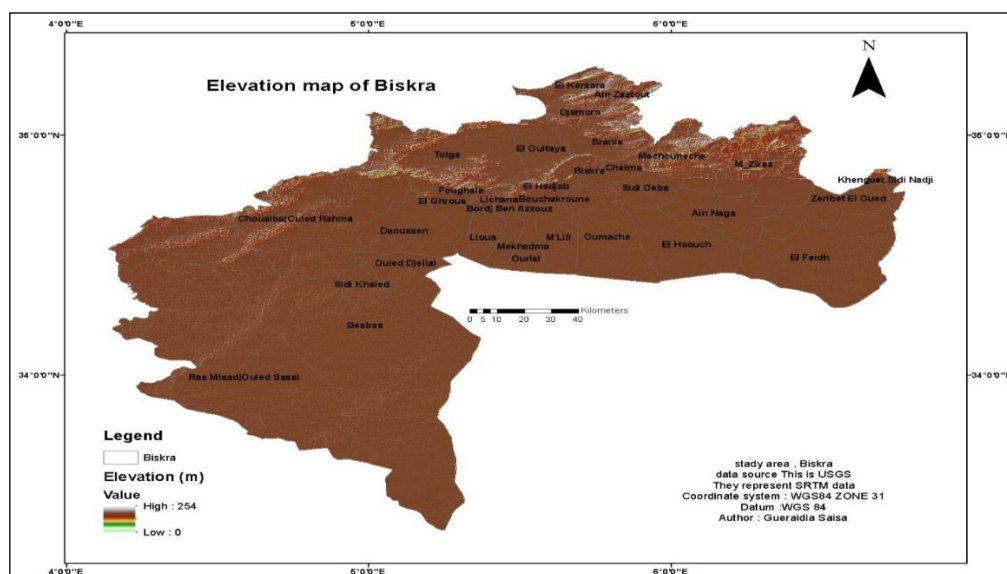


Figure 2: Elevation map of study area.

Source: Authors, (2026).

## II.2 GEOLOGY OF BISKRA REGION

The geological aspect of the Biskra region is defined by sedimentary rocks that span from the Barremian period at the bottom to the Quaternary period at the top, as depicted in Figure 3. These rocks are composed of alluvial deposits of sand and clay, along with tertiary sandstone and sandy clay, as well as limestone formations. The limestone formations have fractures and folds that are oriented in a North-South and Northeast-Southwest direction [5].

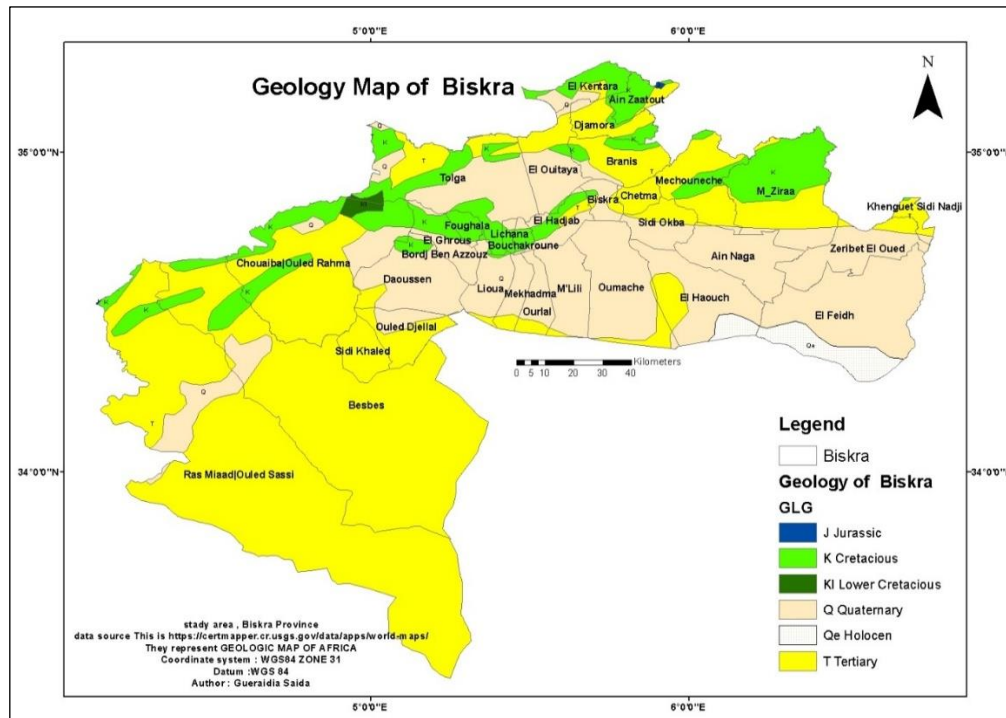


Figure 3: Geology map of Biskra region.  
Source: Authors, (2026).

## II.3 SOILS OF BISKRA REGION

Soil is a fundamental component of the natural environment that is interconnected with structure, vegetation, climate, and human activities. The quality of soil plays a critical role in both agricultural development and the risk of soil collapse in a region. The soil classification follows international standards [6]. Figure 4.

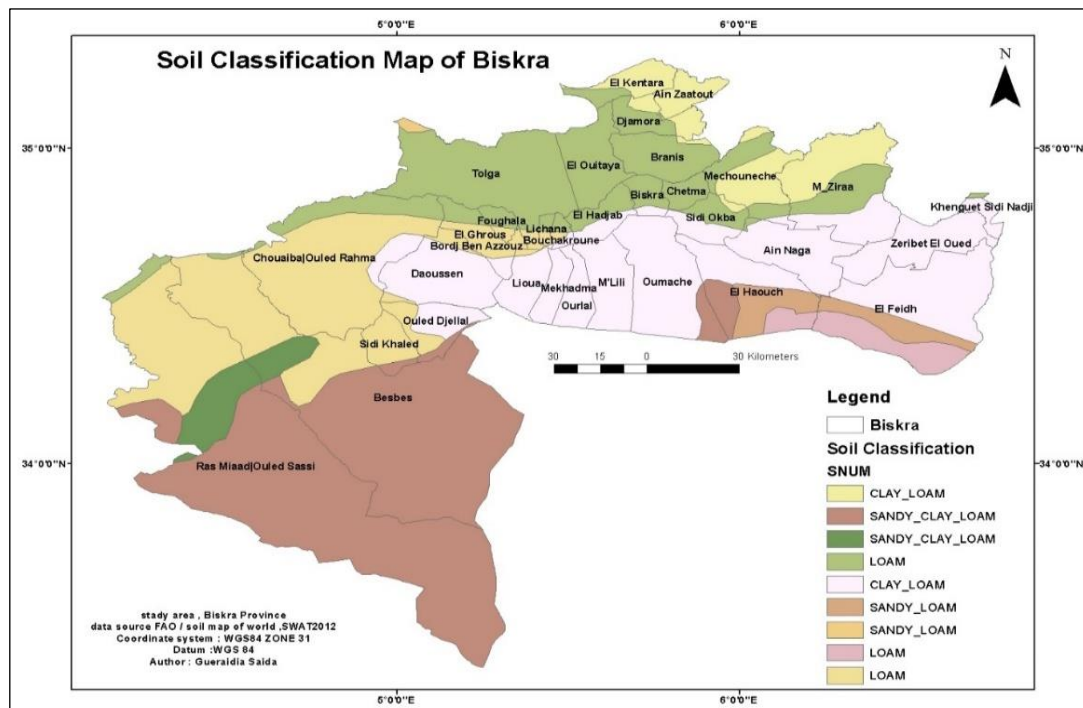


Figure 4: Soil classification Map of Study area.  
Source: Authors, (2026).

## II.4 HYDROGRAPHY AND WATER RESOURCES

The Biskra region contains several wadis that form a basic hydrographic system, which is only active during winter or periods of heavy rainfall. These wadis are part of the broader Saharan watershed of Chott Melghir. Figure 5. Wadi Djeddi is the primary wadi in the Biskra region and covers a drainage area of 9130 km<sup>2</sup>. It serves as a runoff water collector for a significant portion of the southern slopes of the Saharan Atlas. Wadi El Arab is situated in the eastern section of the region and originates from the mountains in the eastern part of the Aurès. It flows into the depression zone of Chott Melghir. Wadi El Abiod is located in the central part of the region and hosts the Fom El Gherza dam. Wadi Biskra passes through the El Outaya plain and contains numerous streams that collect runoff water from the southwest Aurès Mountains.

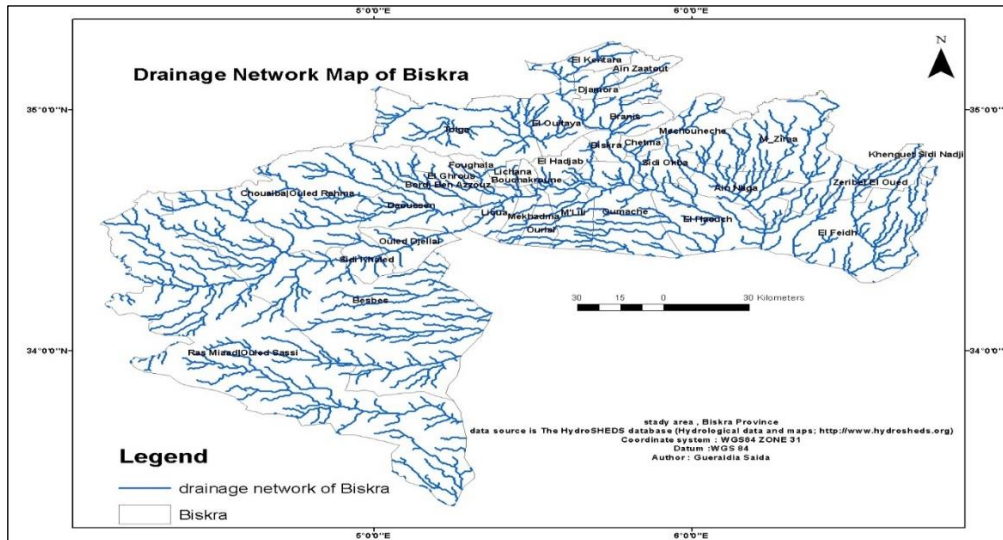


Figure 5: Hydrographic network of Biskra region.  
Source: Authors, (2026).

## II.5 CLIMATOLOGICAL CONTEXT

The recharge of aquifers in the Biskra region is greatly impacted by climatic conditions, with precipitation being the key factor that drives it. However, the region experiences irregularities in both inter-annual and intra-annual rainfall patterns, with an average annual rainfall of approximately 118.75 mm over a 71-year period (1960-2021). The year 2014 had a peak of around 297 mm. Other climatic conditions, such as evapotranspiration and temperature, also have a significant influence on the various aspects of precipitation. Groundwater management in arid regions requires sustainable approaches to balance supply and demand [7]. Over a period of 30 years (1991-2021), the Biskra region indicated a thermal pattern with high temperatures in summer and relatively lower temperatures in winter, with the hottest months being July and August with a maximum temperature of 29.1°C and January being the coldest month with an average temperature of 8.7°C. Precipitation mapping in eastern Algeria shows high spatial and temporal variability [8]. Figure 6 and 7.

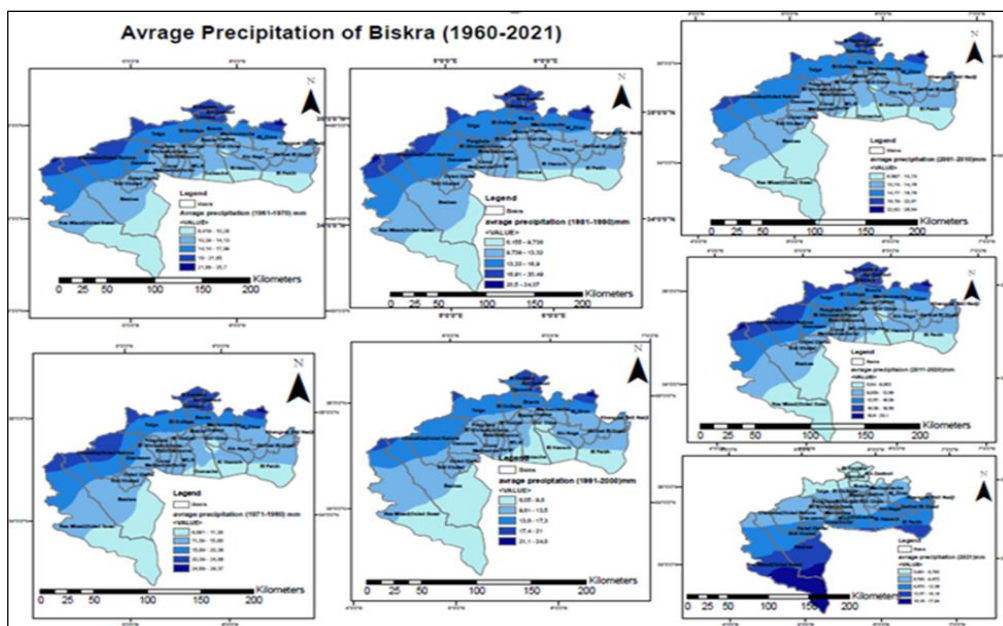


Figure 6: average precipitation of Biskra (1960-2021).  
Source: Authors, (2026).

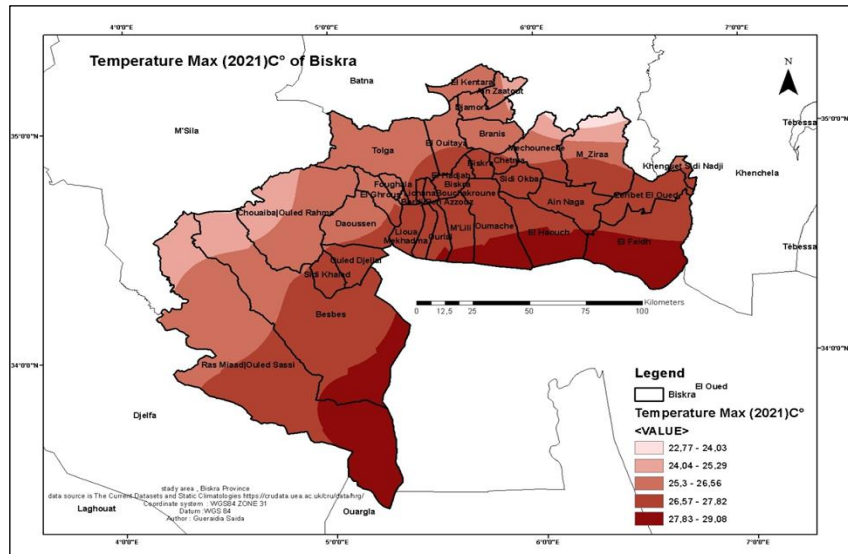


Figure 7: Average temperature Max of Biskra region.  
Source: Authors, (2026).

### III. DATA AND METHODS

#### III.1 FIELD AND LABORATORY INVESTIGATIONS

An investigation was conducted to evaluate the collapse potential of soils through various laboratory and field methods. The study focused on the index properties and hydro-collapsibility characteristics of loess deposits located in the southern region of Algeria. In order to perform laboratory tests, undisturbed soil samples were obtained from 6- to 7-meter-deep pits using a core drilling deep sampler device. These samples were trimmed and waxed carefully into 70mm diameter cylinders of 440mm length.

#### III.2 DATA USED

The research methodology used in the study is presented in Figure 2, which involved creating a digital elevation model (DEM) of the study area using ArcGIS software version 10.8 and data obtained from a field survey listed in Table 1. The DEM was generated through spatial interpolation using Inverse Distance Weighted (IDW) method, which depends on the distance between known and unknown points, resulting in a DEM with a precision of less than ten meters. Remote sensing and GIS have been widely used for environmental assessment in fractured terrains [9]. Figure 3 shows the final DEM for the study area, generated through the field survey method, which is considered more accurate than free DEMs from satellites based on previous studies. Landsat 8 satellite data can be used for land surface temperature mapping and terrain analysis [10]. Digital elevation models can be enhanced using radar interferometry techniques [11]. This method allowed the researchers to perform necessary analyses and accurately depict the terrain of the study area.

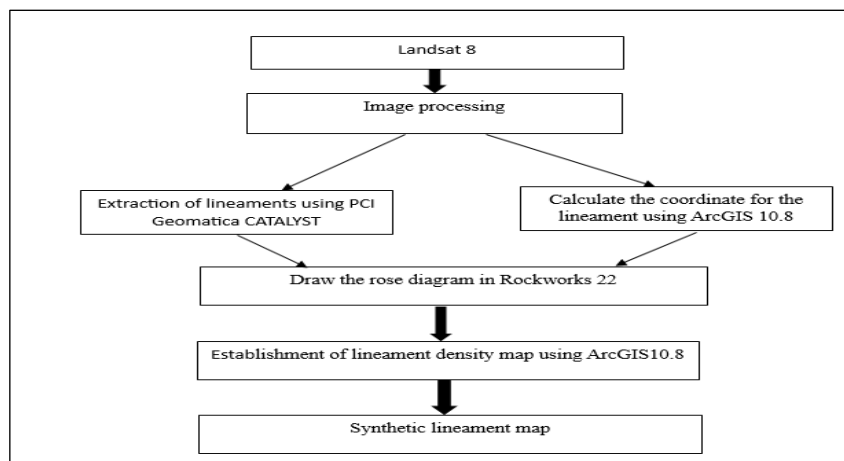


Figure 8: Flowchart of the processing methodology.  
Source: Authors, (2026).

### IV. RESULTS AND DISCUSSIONS

#### IV.1 RESULTS AND DISCUSSIONS

The identification of physical characteristics and bearing capacity tests of the tested soil led to the results presented in Table 1. The soil classification followed the French GTR guidelines [12].

Table 1. Physical and mechanical characteristics of the investigated soil.

| Désignation | Cc   | Cu    | GS   | W <sub>0</sub> | WL%   | WP%   | IP%   | $\gamma_{dmax}$<br>(g/cm <sup>3</sup> ) | w <sub>opt</sub><br>% | %<2<br>$\mu$ m | VBS  | CaCO <sub>3</sub> |
|-------------|------|-------|------|----------------|-------|-------|-------|-----------------------------------------|-----------------------|----------------|------|-------------------|
| Value       | 5.88 | 10.55 | 2.59 | 11.12          | 26.63 | 15.37 | 11.37 | 1.95                                    | 9.43                  | 11.73          | 2.65 | 12.23             |

Source: Authors, (2026).

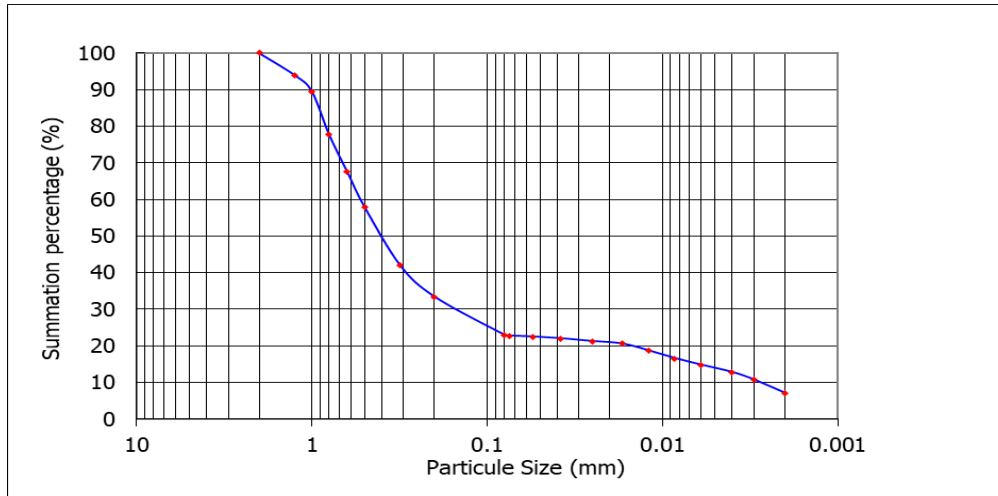


Figure 9: The grain size distribution curve.

Source: Authors, (2026).

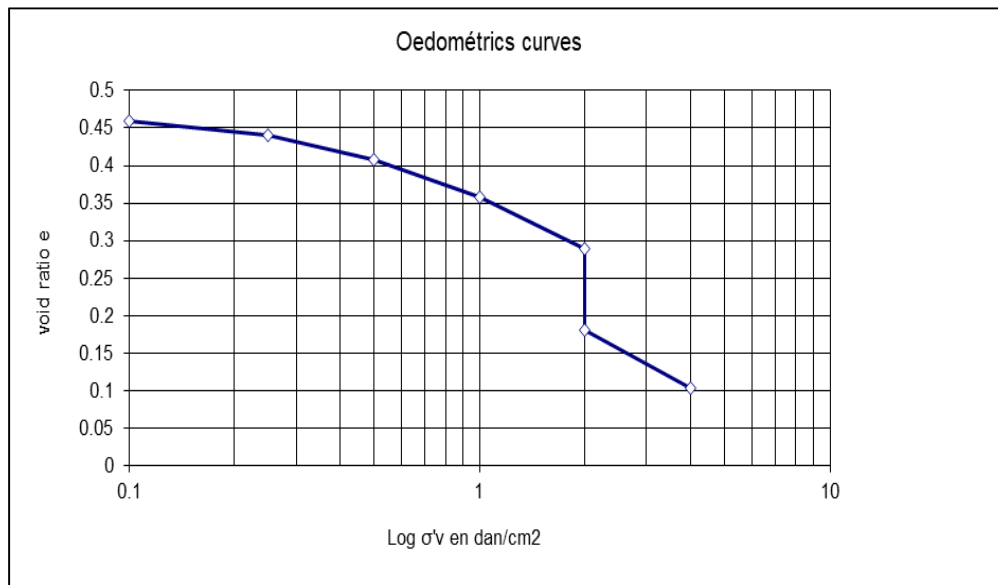


Figure 10: Oedométric curve.

Source: Authors, (2026).

Similar experimental approaches for predicting soil collapse were proposed by Laouar [13]. Loessic soils exhibit specific mechanical behavior under cyclic loading [14]. The compressibility test, according to the procedure described by Jennings and Knight [15], indicates that the soils in question have collapse potentials:  $C_p$  soil 1 = 7.65%. This value exceeds typical thresholds for collapsible soils. Therefore, collapse is likely.

#### IV.2 TOPOGRAPHIC CONTOUR MAP LINES

Topographic contour lines are a common method used to depict the surface of a landscape, which not only conveys its geometry but also implicitly preserves the topology of the earth's surface. To illustrate the height of the contour lines, elevation values are often given as text descriptions on topographic maps. Besides contour lines, spot altitudes are available, represented by dots or crosses, to indicate significant natural features in a prominent region, such as hilltops, knolls, isolated summits, mountaintops, mountain passes, saddles, and other high points. Due to the mountainous terrain of the small watershed, the watershed contour map displayed in Figure 11 has contour lines ranging from 0 to 1800 meters. The watershed's water divisions are mostly mountainous.

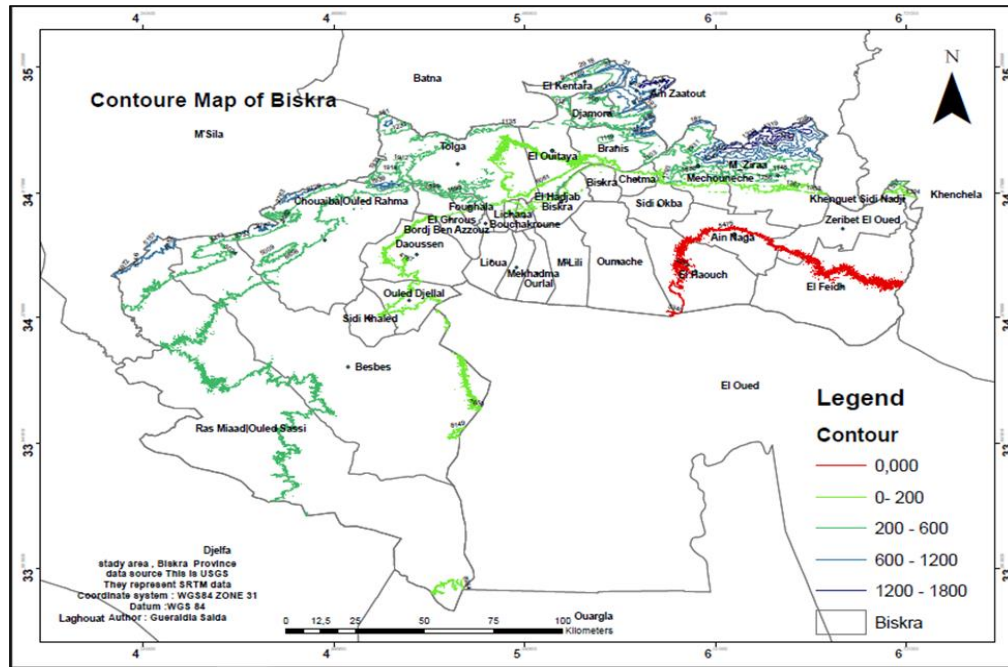


Figure 11: contour map of region study area.

Source: Authors, (2026).

#### IV.3 ASPECTS MAP

The significance of aspect and elevation maps in understanding the microclimate and vegetation distribution of a mountainous area. The aspect map helps in identifying vegetation types and their distribution while the elevation map indicates the effect of sunlight on the area's microclimate. The DEM display map illustrates the direction of the slope, and in the case of the Biskra watershed, the east-facing slopes have more vegetation and moisture than the west-facing slopes.

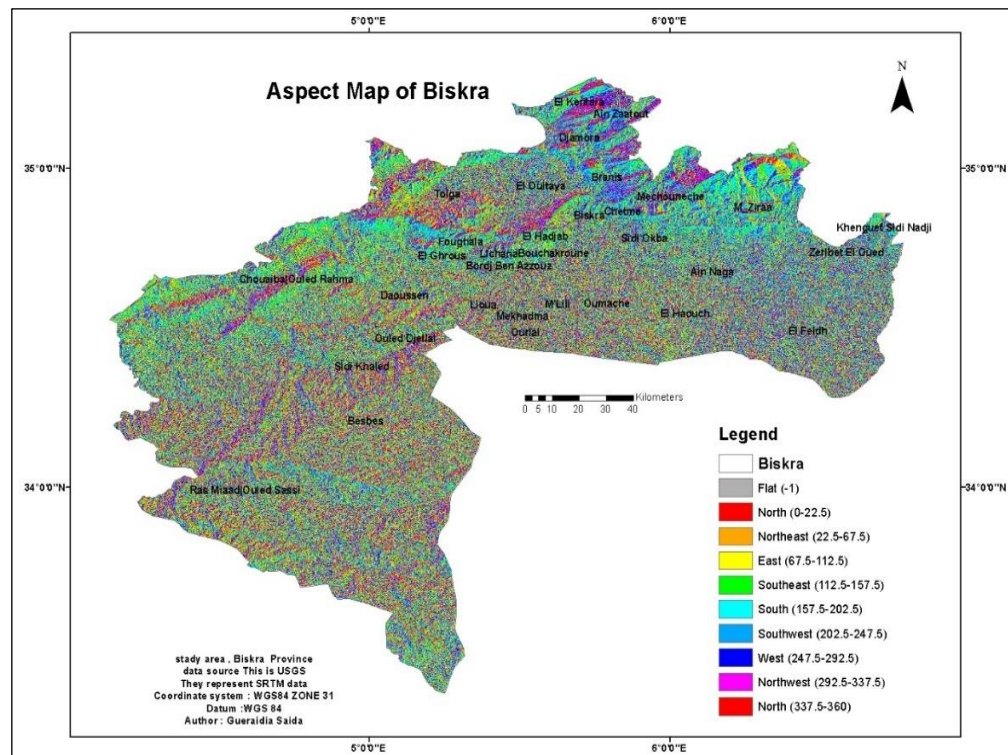


Figure 12: aspect map of study area.

Source: Authors, (2026).

#### IV.4 SLOPE MAP

To generate a slope map of the study area, the digital elevation model was converted from its original unit in degrees to units of length. The slope of the map, displayed in Figure 13, was measured in degrees using ArcGIS software 10.8. The map shows that the low slope is 0 degrees, and the high slope is 3.16 degrees, with the average slope of the study area being about 3.61 degrees.

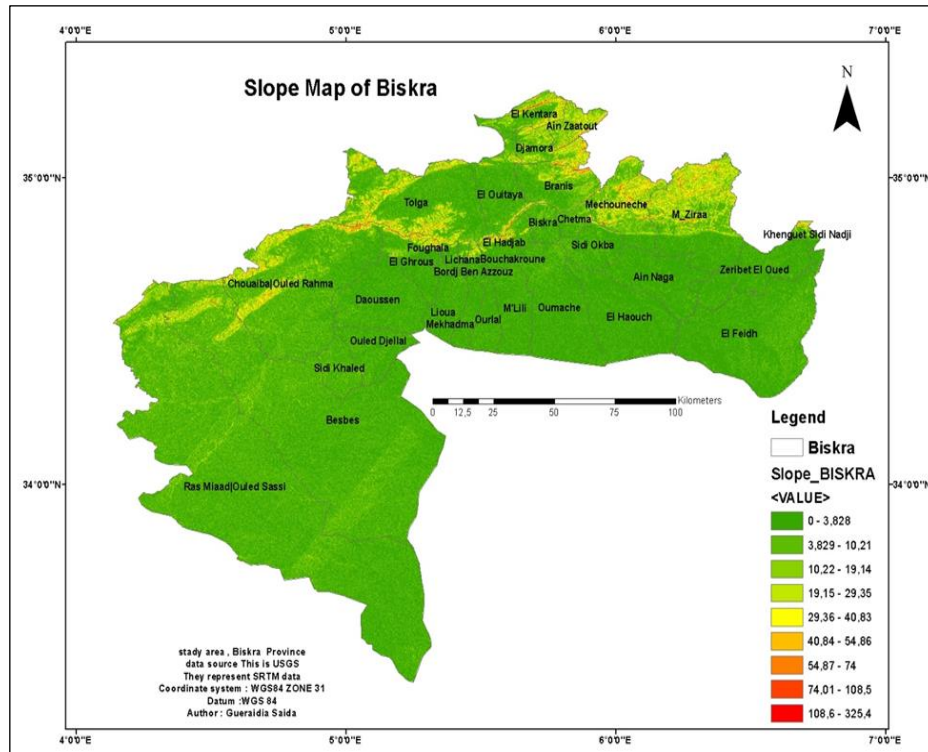


Figure 13: slope map of study area.  
Source: Authors, (2026).

#### IV.5 LINEAMENTS MAP

A lineament is a substantial and elongated feature that can be observed in satellite images based on the topographic characteristics and straight tonal alignments of the underlying structure. Lineaments can be identified by visually interpreting Landsat image data and are often considered promising areas for soil collapse. Lineament extraction from satellite images has been successfully applied in various geological settings [16]. They are commonly found in regions with soil collapse hazards, with the most prevalent orientations in the study area being towards NNE-SSW, NE-SW, NW-SE, and NS directions. Regional fault mapping helps understand hydrodynamics in fractured basement zones [17]. Figure 14.

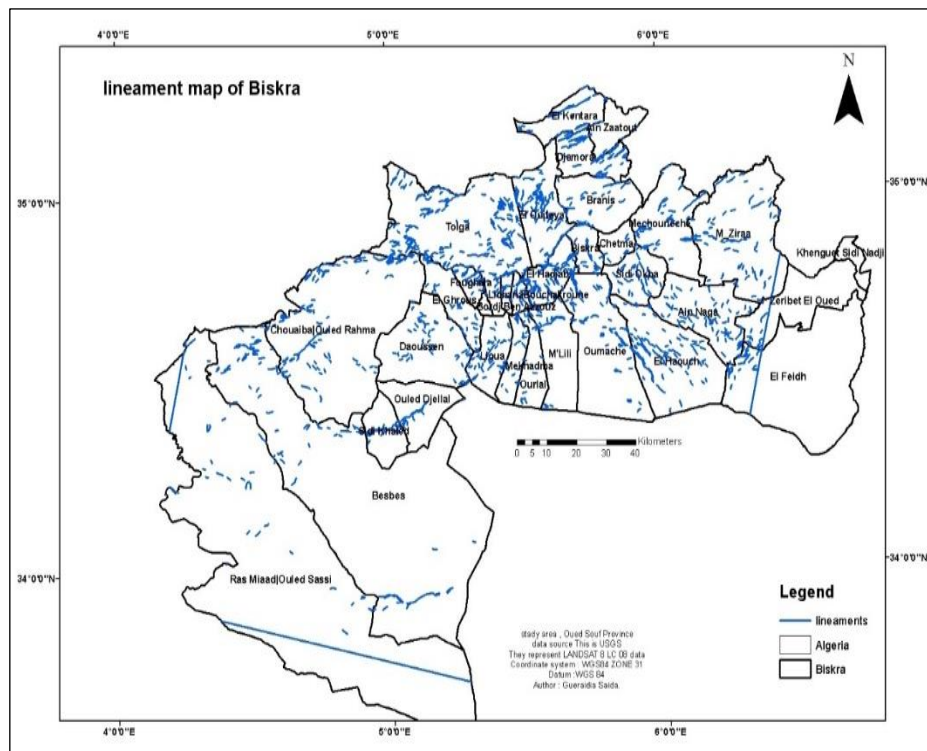


Figure 14: lineaments map of study area.  
Source: Authors, (2026).

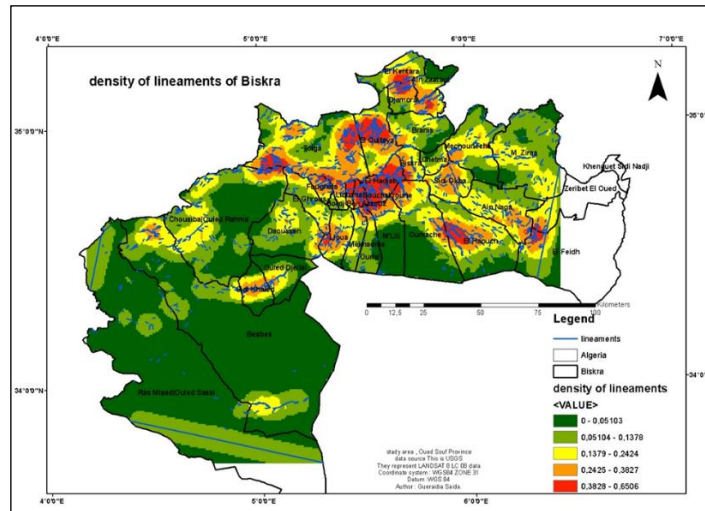


Figure 15: lineaments density map of Biskra.  
Source: Authors, (2026).

Figure 15 shows the lineament density map of the study basin, created by utilizing GIS (Geographic Information System) techniques on the lineament map obtained from Landsat 8 satellite images. The area was divided into equal grids, and the number of lineaments in each grid was counted and recorded to calculate the frequency of lineaments per unit area. The lineament density analysis aims to identify areas with high lineament density. The map illustrates that the study basin has three areas with a high lineament density (0.65 km/mesh), which are located in the central, south-west, and north-east parts. This high density indicates tectonic movements that have influenced the geological formations over time. Most of the study area also shows a high lineament density, as depicted in the map.

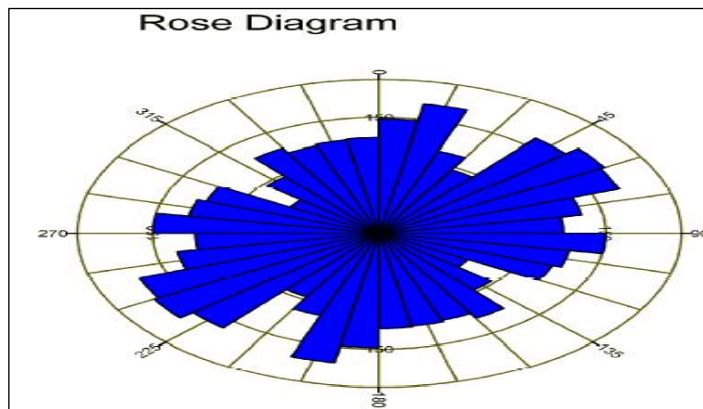


Figure 16: rose diagram lineaments.  
Source: Authors, (2026).

Table 2 :interpretation of rose diagram lineaments.

| Statistical Summary                       |               |
|-------------------------------------------|---------------|
| Calculation Method :                      | Frequency     |
| Class Interval :                          | 10.0 Degrees  |
| Azimuth Filtering :                       | Deactivated   |
| Data Type :                               | Bidirectional |
| Population :                              | 2349          |
| Total Length of All Lineations :          | 4698.0        |
| Maximum Bin Population:                   | 172.0         |
| Maen Bin Population :                     | 130.5         |
| Standard Deviation of Bin population :    | 27.51         |
| Maximum Bin Population (%) :              | 3.66          |
| Maen Bin Population (%):                  | 2.78          |
| Standard Deviation of Bin population (%): | 0.59          |
| Maximum Bin Length :                      | 172.0         |
| Mean Bin Length :                         | 130.5         |
| Standard Deviation of Bin Lengths         | 27.51         |
| Maximum Bin Length (%) :                  | 3.66          |
| Mean Bin Length (%):                      | 2.78          |
| Standard Deviation of Bin Lengths (%)     | 0.59          |
| Vector Mean                               | 47.4 Degrees  |

Source: Authors, (2026).

## V. CONCLUSIONS

This experimental research, conducted in the Biskra region, has provided a comprehensive understanding of soil behavior, especially concerning collapsible loamy clay. The obtained results constitute an important database for geotechnical investigation and rheological behavior modeling. The characteristics of compressibility and consistency confirm that the soil is collapsible. The integration of remote sensing and geotechnical data provides a comprehensive approach for collapse risk assessment [18]. The satellite images were used to map the majority of the lineaments found in Biskra province, and the fractures in the area were analyzed to determine the prevailing orientations. Statistical analysis revealed that the lineaments were mainly oriented in the NE-SW, NW-SE, E-W, and N-S directions. The NW-SE direction, which is most prominent in the northern sector, corresponds to the primary direction of the drainage network. The intensity of fracturing was studied, and it was discovered that the northern, central, and southern regions of the study area had high levels of fractures.

## VI. AUTHOR'S CONTRIBUTION

**Conceptualization:** Saida Gueraidia, Med Salah Laouar, Nour El Houda Gueraidia, Rayene Sirine Ramdani, Chems Eddine Fehdi.

**Methodology:** Saida Gueraidia, Nour El Houda Gueraidia, Rayene Sirine Ramdani.

**Investigation :** Saida Gueraidia, Med Salah Laouar, Nour El Houda Gueraidia.

**Discussion of results:** Saida Gueraidia, Med Salah Laouar, Nour El Houda Gueraidia, Rayene Sirine Ramdani, Chems Eddine Fehdi.

**Writing – Original Draft:** Saida Gueraidia, Med Salah Laouar.

**Writing – Review and Editing:** Saida Gueraidia, Nour El Houda Gueraidia, Rayene Sirine Ramdani.

**Resources:** Saida Gueraidia, Med Salah Laouar.

**Supervision:** Chems Eddine Fehdi.

**Approval of the final text:** Saida Gueraidia, Med Salah Laouar, Nour El Houda Gueraidia.

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