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Natural hazard processing analyze investigation using different spectral indices (ndvi, ndwi, mdwi, savi, ndbi, nbr) case study of souk ahras area north-est of algeria.

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Abstract

This study seeks to create a model for assessing the susceptibility of different natural hazards based on land use and cover characteristics in Souk Aras area, North-Est of Algeria, utilizing data from Landsat 8 satellite imagery. Parameters such as NDVI, NDWI, MDWI, and NDBI are employed. For instance, NDWI and MNDWI values between 0.00 and -0.37 indicate the presence of water surfaces along coastlines, while MSAVI values ranging from -0.21 to -0.37 suggest areas lacking vegetation. Similarly, NDBI values from 0.17 to 0.22 signify the presence of built-up areas with socio-economic activities, whereas NDVI values between 0.22 and 0.32 denote areas with vegetation densities, biomass growth, and moderate to low vegetation health. Additionally, the analysis of digital elevation models reveals that regions characterized by high socio-economic activity, low NDVI, elevated NDWI/MDWI, high MSAVI, and high NDBI are situated in low-elevation areas, indicating a heightened vulnerability to natural hazards.

Key Words: *NDVI, NDWI, MDWI, SAVI, NDBI, NBR, landsat 8.*

Introduction

The acquisition of land cover imagery in disaster-prone regions like Souk Ahras by the Landsat 8 satellite hinges on soil and vegetation characteristics, laying the groundwork for remote sensing methodologies in land cover analysis (Rendana et al., 2016). Over the past five years, the assessment of land cover has heavily relied on vegetation indices, incorporating techniques for both spatial and temporal analysis of disaster-affected areas (Holzman, Rivas & Bayala, 2014; Mallick, Bhattacharya & Patel, 2009). Through digital image processing, satellite data enables analysis employing various algorithms and mathematical indices, guided by reflectance characteristics to pinpoint notable features within the images (Xie et al., 2010). The model developed in this research aims to monitor areas susceptible to natural hazards like landslides, floods, and fires in Souk Ahras. It seeks to construct a vulnerability assessment model focusing on land use and cover, utilizing data from Landsat 8. The model integrates information from normalized differential vegetation index (NDVI), normalized difference water index (NDWI),

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modified difference water index (MDWI), and normalized difference built-up index (NDBI) vegetation indices.

Figure 1 location map of Souk Ahras area

Research Methods

This section presents a research method for identifying areas prone to natural hazards. The algorithm incorporates atmospheric correction to mitigate potential noise in the data, which could otherwise affect prediction accuracy and classification performance.

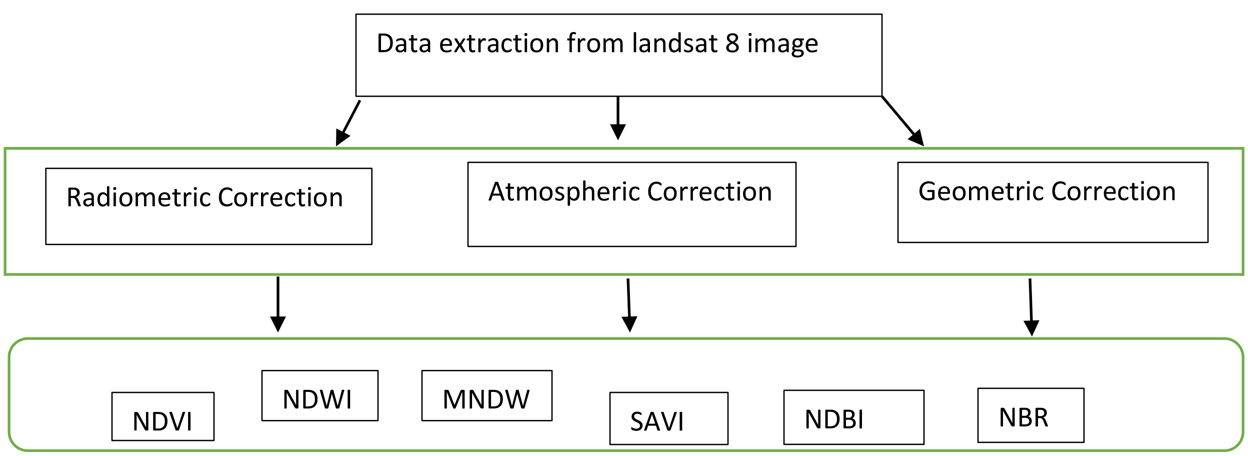

Figure 2. Experimental procedure of the satellite imagery

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1. Data extraction

The Landsat 8 image data obtained from https://earthexplorer.usgs.gov/ in digital format can be utilized for land use mapping purposes. The data comprises 11 bands, labeled as Band 1 through Band 11, each possessing distinct names and wavelengths ranging from 0.43 to 12.51. Table 1.

Table 1. Landsat 8 Spectral Band.

Band	Wavelength in µm.	Resolution in m
B 1 Aerosol	0.43-0.43	30
B2 Blue	0.45-0.51	30
B3 Green	0.53-0.59	30
B4 Red	0.6-0.64	30
B5 NIR	0.85-0.88	30
B6 SWIR 1	1.57-1.65	30
B7 SWIR 2	2.11-2.29	30
B8 Panchromatic	0.50-0.68	15
B9 Cirrus	1.36-1.38	30
B10 Thermal 1	10.60-11.19	100*30
B11 Thermal 2	11.50-12.51	100*30

2. Atmospheric correction

The data obtained through extraction retains a low level of radiometric precision due to inherent errors during sensor recording in image acquisition. Consequently, for applications such as biomass assessment, vegetation index computation, and land-cover classification, atmospheric correction becomes imperative to enhance data accuracy. This correction procedure aims to refine image classification precision, allowing for data comparison and organization essential for evaluating areas prone to tsunamis. Within this correction process, the removal of atmospheric haze and cloud cover holds particular importance, as it optimizes satellite imagery clarity, thereby facilitating the identification of shifts in land cover and land use.

3. Data pre-processing

Initially, understanding geometric and radiometric corrections is crucial. Geometric correction entails adjusting the coordinates of each pixel in the image to accurately represent its location on the Earth's surface, accounting for factors like satellite movement, Earth rotation, and terrain effects. On the other hand, radiometric correction serves a distinct purpose. The data preprocessing stage involves acquiring Landsat 8 satellite imagery from www.earthexplorer.usgs.gov. These images undergo not only geometric but also radiometric and atmospheric corrections.

Following image correction, the calculation of clean bands is performed based on specific formulas for each index. The extraction of Landsat 8 image data involves applying formulas for NDVI, NDBI, NDWI, and MNDWI. The results of this extraction yield numerical values suitable for classification and prediction purposes. The NDVI, MNDWI, NDWI, and NDBI formulas are elaborated as follows.

- Normalized Difference Vegetation Index (NDVI)

NDVI is a widely utilized vegetation index employed for assessing the degree of greenness (chlorophyll content) in plants.

$$NDVI\ = (BAND\ 5 - BAND\ 4) \div (BAND\ 5 + BAND\ 4)$$

- Normalized Difference Water Index (NDWI)

NDWI is an index indicating the moisture content of a particular area. The formula for MNDWI index is:

$$NDWI\ = (BAND\ 3 - BAND\ 4) \div (BAND3 + BAND5)$$

- Modified Normalized Difference Water Index (MNDWI)

MNDWI is a variation of the NDWI index, characterized by a specific formula.

$$MNDWI\ = (BAND\ 3 - BAND\ 6) \div (BAND\ 3 + BAND\ 6)$$

- Soil Adjusted Vegetation Index (SAVI)

SAVI serves to adjust NDVI by reducing the impact of soil brightness in regions with sparse vegetation, employing a soil-brightness correction factor (L). SAVI is determined by computing the ratio of Red and NIR values with a soil brightness correction factor, typically set at L=0.5, suitable for various land cover types.

$$SAVI\ = \left(\frac{NIR - RED}{NIR + RED + L}\right) \times (1 + L) = \left(\frac{BAND\ 5 - BAND\ 4}{BAND\ 5 + BAND\ 4 + 0.5}\right) * 0.5$$

- Normalized Difference Built-up Index (NDBI)

NDBI is a valuable transformation/index utilized for automated mapping of built-up areas within a region using Landsat images.

$$NDBI\ = (BAND\ 6 - BAND\ 5\ ) \div (BAND\ 6 + BAND\ 5)$$

- Normalized Burn Ratio (NBR)

Is calculated as ratio between the NIR (BAND 5) and SWIR (BAND 7) in landsat 8

$$NBR = (BAND\ 5 - BAND\ 7) \div (BAND\ 5 + BAND\ 7\ )$$

Results and Discussions

The dataset comprised Landsat 8 image data, encompassing 11 bands detailed in Table 1. All 11 bands underwent processing in ArcGIS to compute the necessary indices: NDVI, NDBI, MNDWI, NDWI, and SAVI, NBR. Each index was then determined.

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Figure 3 presents a map delineating areas prone to landslides based on the NDVI index. Elevated NDVI values indicate greater vegetation density, hence a lower risk of landslides, depicted in bluish hues. Conversely, regions at high risk of landslides exhibit colors nearing red, indicating lower NDVI values and consequently sparse vegetation.

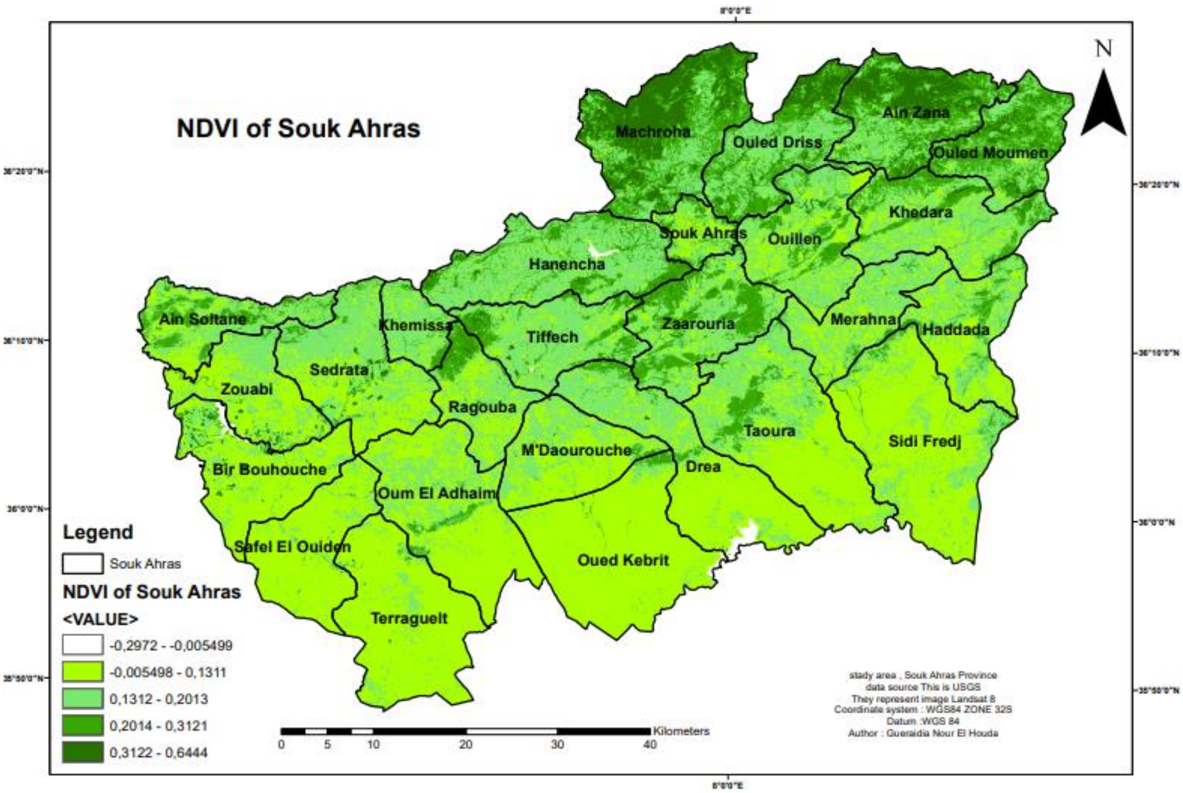

Figure 3. NDVI of Souk Ahras area

The NDBI maps reveal an urban expansion across Souk Ahras Figure 4The central area is notably characterized by built-up regions, extending further northward. Within the central area, there is a prevalence of high-density built-up regions surrounded by lower density areas. Towards the end of the map, the built-up regions appear to saturate, yet the concentration of high-density built-up areas remains evident in the central region. Growth is particularly noticeable in the north, northwest, and northeast directions.

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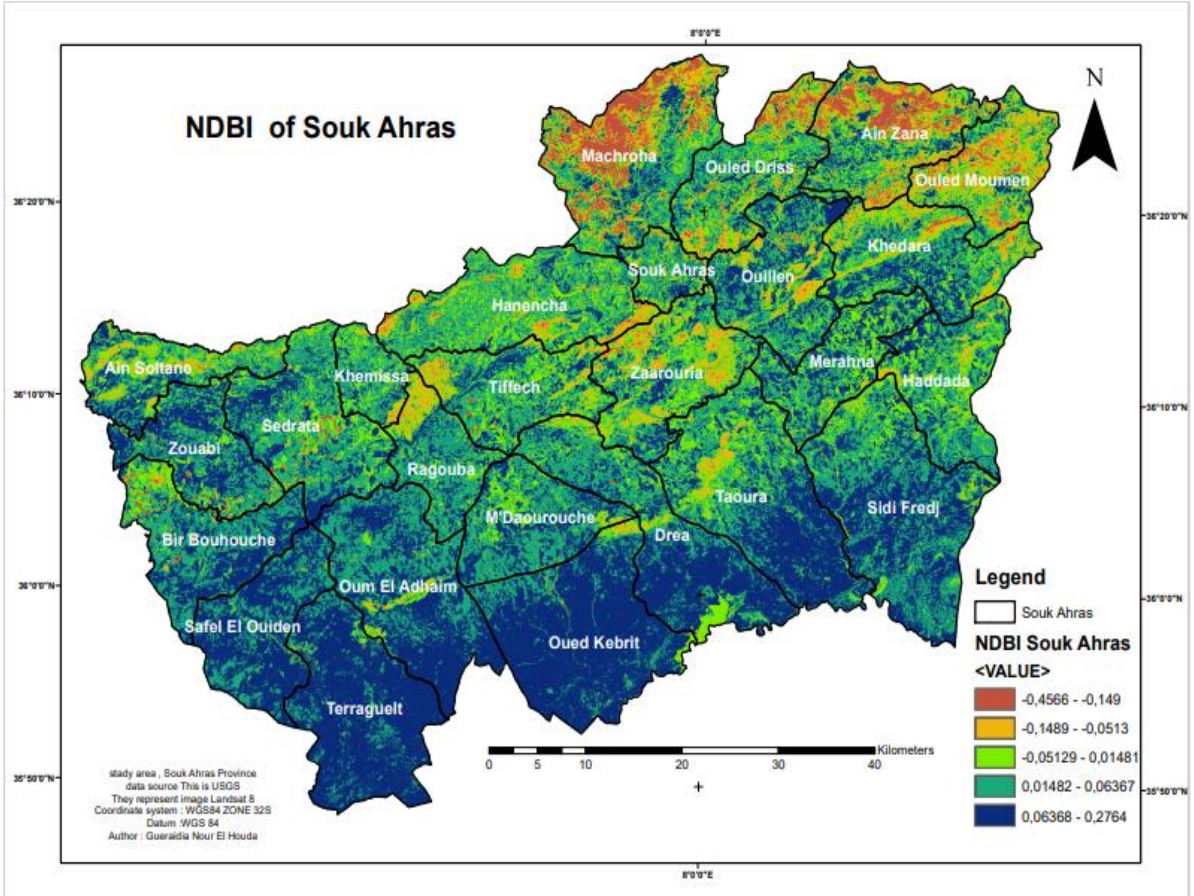

Figure 4. NDBI of Souk Ahras area

Figure 5 depicts the map outlining areas at risk of landslides based on the NDWI index for the year 2023. Regions characterized by water dominance or high wetness levels indicate an elevated risk of landslides, represented by a reddish coloration. Conversely, areas with lower landslide risk display a bluish hue.

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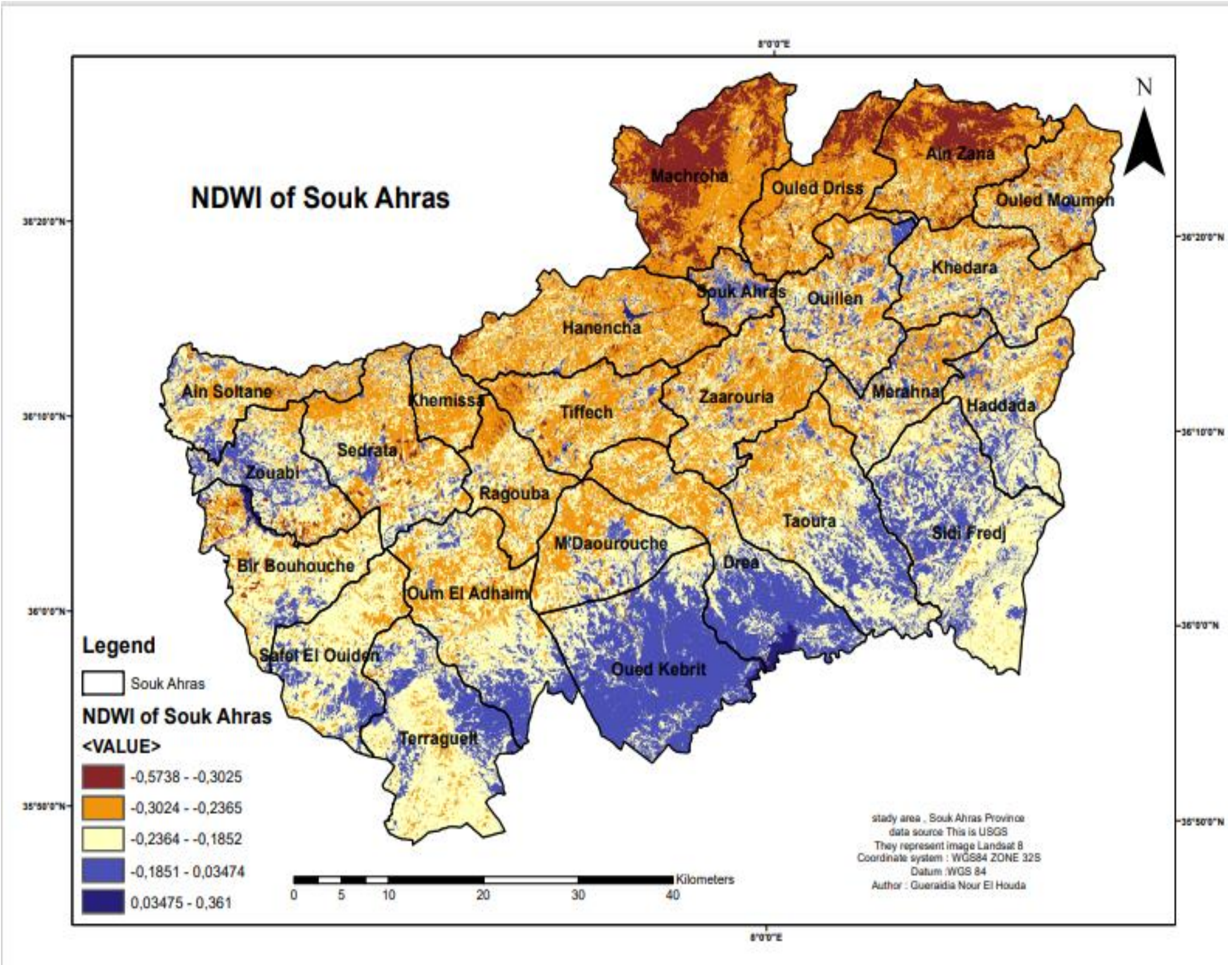

Figure 5. NDWI of study area.

The Modified Normalized Difference Water Index (MNDWI) map provides valuable insights into the distribution of water bodies within the studied area. Areas depicted in darker shades, such as deep blue, likely represent bodies of water such as rivers, lakes, or ponds. Conversely, regions appearing in lighter shades, or even white, may indicate dry land or areas with minimal water presence. The contrast in colors can help identify the extent and density of water bodies, which is crucial for various applications including hydrological studies, urban planning, and environmental monitoring. Additionally, changes in MNDWI values over time can signify alterations in water levels or the occurrence of water-related events such as flooding or drought. figure 6.

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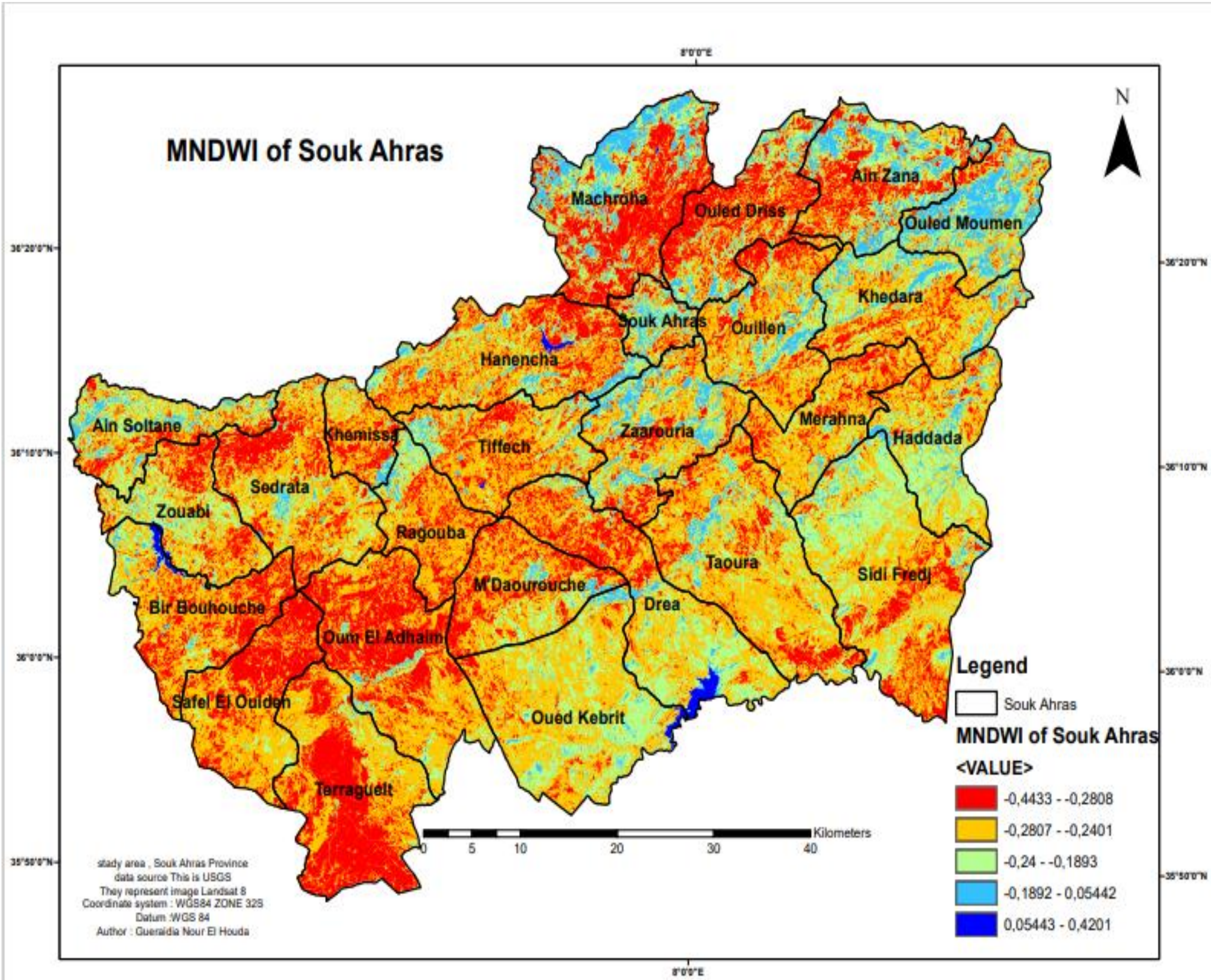

Figure 6. MNDWI of study area.

The SAVI index portrays areas adjusted based on their soil type or geographical features. A higher SAVI value signifies forested vegetation, while a lower value indicates water bodies such as rivers. In Figure 7, areas depicted in reddish tones indicate low SAVI values, suggesting high vulnerability to landslides due to the presence of water bodies, asphalt, and pavement. Conversely, blue areas denote lower vulnerability to landslides. Figure 7 also presents the distribution map of landslides risk areas based on the SAVI index for the year 2023.

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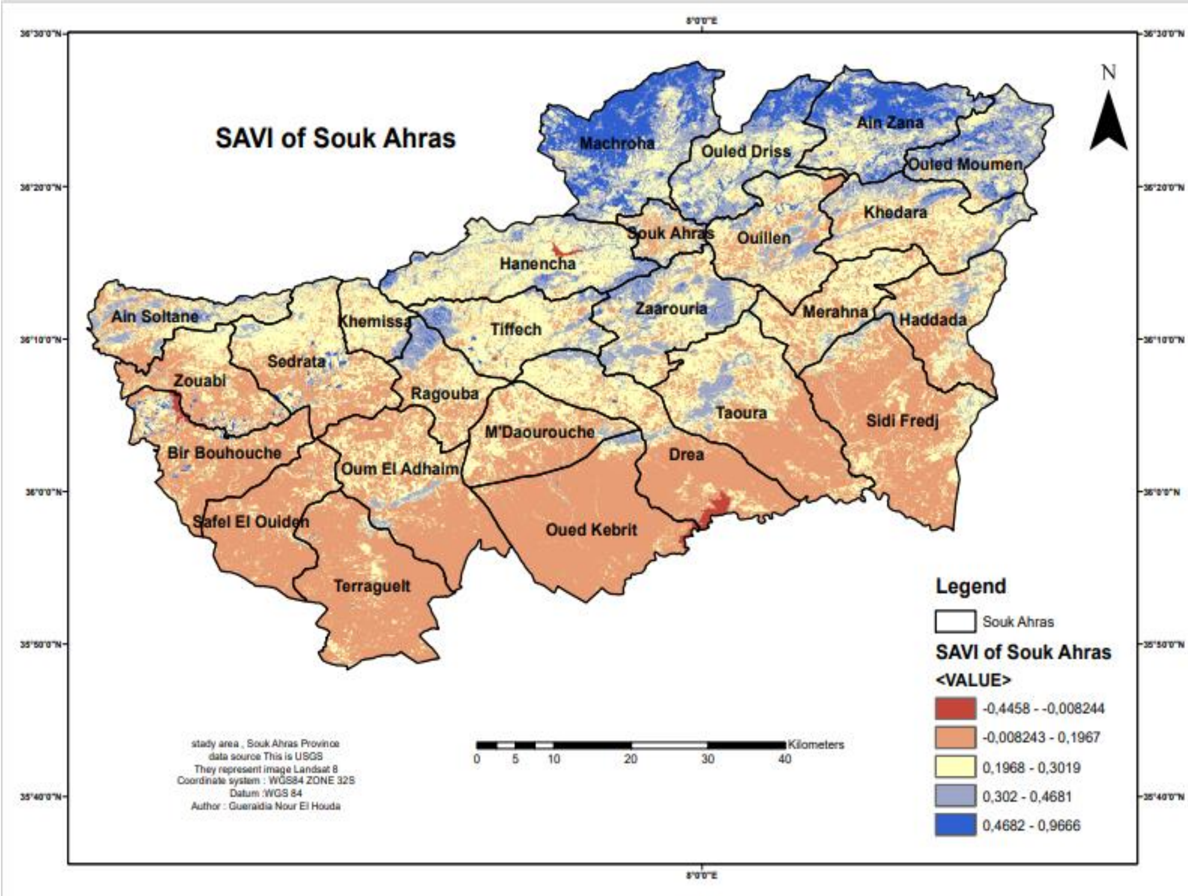

Figure 7. SAVI of study area.

The Normalized Burn Ratio (NBR) map offers insights into the severity and extent of fire-affected areas within the studied region. Darker shades on the map, such as deep red or black, typically indicate regions where vegetation has been significantly affected by fire. These areas may represent areas of intense burning or complete vegetation loss. Lighter shades, on the other hand, may indicate less severe burning or areas where vegetation remains relatively intact. Analyzing the distribution and intensity of burnt areas can help assess the ecological impact of fires, identify areas requiring immediate intervention for restoration or rehabilitation, and inform land management strategies to mitigate the risk of future fires. Additionally, monitoring changes in NBR values over time can provide valuable insights into long-term trends in fire occurrence and vegetation recovery. Figure 8.

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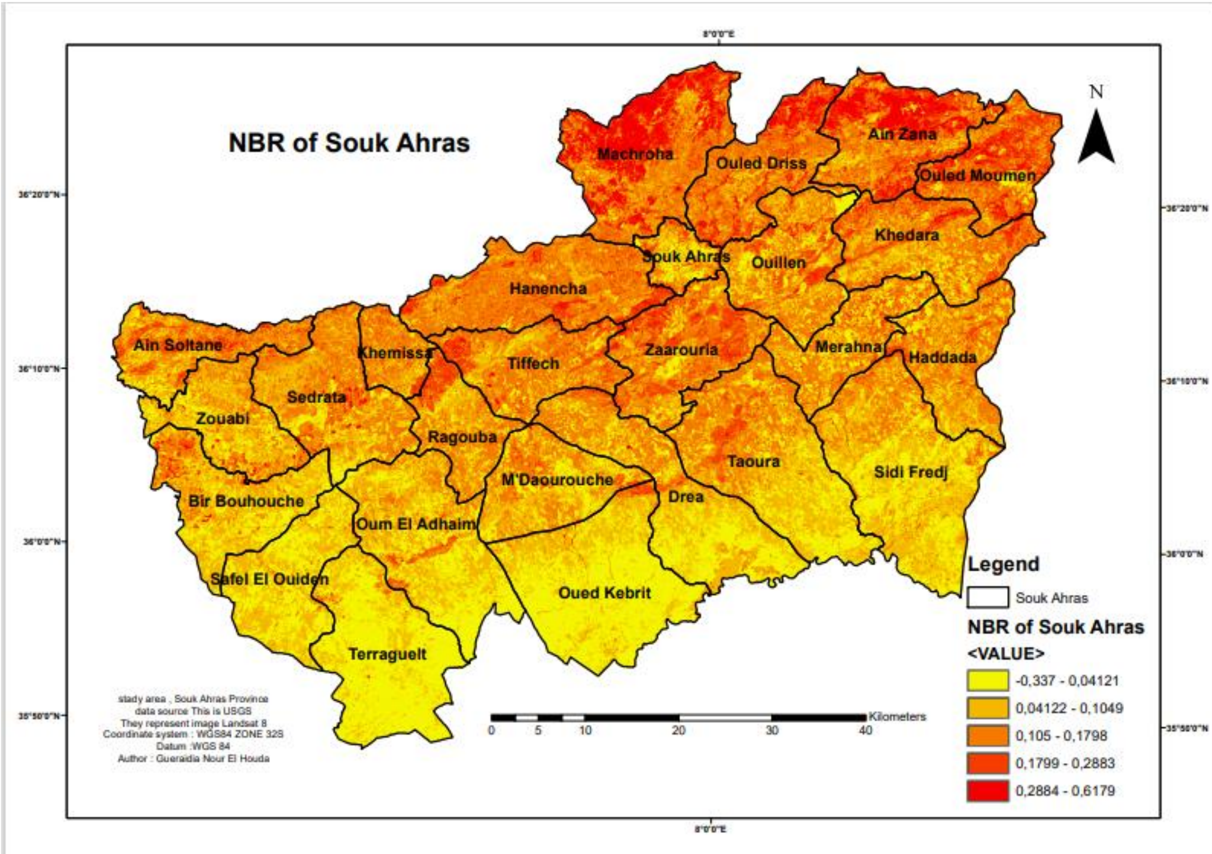

Figure 8. NBR of Souk Ahras.

Conclusion

In conclusion, the combination of various remote sensing indices provides valuable insights into areas susceptible to landslides, aiding in hazard assessment and mitigation efforts.

NDVI (Normalized Difference Vegetation Index) highlights areas with dense vegetation cover, which can stabilize slopes and reduce landslide risk. Conversely, low NDVI values may indicate sparse vegetation or barren terrain, potentially increasing susceptibility to landslides.

NDWI (Normalized Difference Water Index) and MNDWI (Modified Normalized Difference Water Index) identify water bodies, which can weaken soil stability and contribute to landslide occurrence, particularly in areas with high moisture content.

SAVI (Soil Adjusted Vegetation Index) accounts for soil brightness, enabling more accurate assessment of vegetation density and its influence on landslide susceptibility. High SAVI values suggest dense vegetation cover, which can mitigate landslide risk through root reinforcement and soil stabilization.

NBR (Normalized Burn Ratio) can indicate areas affected by wildfires, which can alter soil properties and vegetation cover, potentially increasing landslide susceptibility in burned areas due to reduced vegetation and increased runoff.

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MSAVI (Modified Soil Adjusted Vegetation Index) provides insights into vegetation health and density, with high MSAVI values indicating healthy vegetation cover, which can mitigate landslide risk through soil stabilization and erosion control.

Overall, integrating these indices allows for a comprehensive analysis of landslide hazard potential, enabling informed decision-making and proactive measures to reduce vulnerability in at-risk areas.

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