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Research Article

Study of the impact of desertification on land use in the El Bayadh region, South-Western Algeria

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Abstract

Algeria's steppe rangelands, covering an extensive 32 million hectares, serve as a vital biological zone, functioning as a transitional buffer between the sub-humid northern areas and the parched Sahara to the south. These rangelands are crucial for preserving biodiversity and aiding local inhabitants, although they are progressively susceptible to desertification, a significant environmental peril in Algeria. The wilaya of El Bayadh, a significant steppe area, is notably impacted by this occurrence. This research examines land use alterations in the wilaya of El Bayadh from 1990 to 2022, using remote sensing methodologies and Geographic Information Systems (GIS) alongside Landsat TM satellite images. The aim is to observe the advancement of desertification and delineate the spread of sand deposits in three northern communes: Bougtoub, El Kaf Lahmar, and Tousmouline. The findings demonstrate a significant increase in silting over the research period, indicating substantial changes in land cover. These results emphasize the increasing severity of desertification and stress the need for prompt action to protect this delicate environment. This study offers significant geographical data and analysis, establishing a basis for formulating effective policies and methods to address desertification. Through the implementation of specific strategies, stakeholders and policymakers may alleviate the detrimental impacts of desertification, foster sustainable land use practices, and secure the enduring stability of Algeria's steppe areas. The research highlights the need of using modern geospatial technology to tackle environmental issues and enhance resilience in at-risk ecosystems.

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1. Introduction

Desertification is a global environmental concern. It has been recognized as a significant issue since the early 1970s (Pater, 2021). It arises from an imbalance in the dynamic interactions between several elements in the ecosystem - climate, soil, vegetation and humankind. It is a phenomenon that develops under the combined effects of climate change and human activities applied to fragile soils and vegetation (Bouiadjra et al. 2011; Khalid et al. 2015).

The High Plains of Southern Oran are a pastoral steppe region with a delicate natural environment. The biogeographical characteristics of the steppe, which do not allow for dense settlement, have enabled man to adapt by adopting nomadism as a way of life (Benguerai, 2011). Soil degradation and regression of plant cover results from the combination of factors which drive the soil to an evolution different from the natural evolution linked to the local climate and vegetation (Poletti, 2018; Osman, 2018; Dragović and Vulević, 2020; Smith et al., 2020). Several factors interact, including the arid climate, with recurrent droughts of varying duration and intensity, and human activities, mainly overgrazing, inappropriate mechanized plowing and over-exploitation of pastoral resources. Many researchers have reached the same conclusion (Moulay et al. 2011; Benaradj et al. 2017; Fialho & Zinn, 2014). The wilaya of El Bayadh is part of the high plains of southern Oran and among the steppe wilayas affected by the phenomenon of desertification. Located in south-western Algeria, 600 km from Algiers, it covers an area of 71.697 km^2, or "3**%**" of the national territory (Boussemghoun, 2010).

The research region is a vulnerable habitat where human activities provide a constant threat to the balance of the steppe ecosystem. Multiple pertinent elements influence the soil deterioration process. These variables may be readily identified in current soil ratios (Zaidi et al. 2021; Boukerker et al. 2021). Decision-support tools, like GIS and remote sensing, have become essential for land managers to enhance their understanding of land use and exploitation issues. Regarding the mitigation of desertification, floods, fires, urbanization, and the conservation of natural resources, these instruments provide frameworks for land planning and management (Benguerai, 2011 & Berrichi, 2021).

Using GIS and remote sensing technologies, we are looking at pictures taken between 1990 and 2022 to see how desertification has changed and how sand deposits have grown in the three communes in the northern region of El Bayadh over 32 years.

This work aims to provide an overview of the existing status and the spatio-temporal development of this significant occurrence, facilitating stakeholders in implementing required steps to mitigate desertification in the research region.

2. Materials and methods

2.1 Presentation of the study region

El Bayadh region lies between two watersheds: the watershed of the Oranese high plateaux, which occupies the north of the wilaya, and the Sahara watershed to the south of the region (Dahmani, 2006). The region is located in south-western Algeria, between parallels 30° 42' and 34° 28' north altitude, and between meridians of longitude 0° 24' west, zone 30, and 2° 16' east, zone 31 (Boussemghoun, 2010).

The region stretches over an area of 71697 Km^2, representing "3**%**" of the total surface area of the national territory (National agency for investment development, 2013). Administratively, It is made up of eight districts and twenty-two communes. This area is bordered to the north by the Saïda Tiaret wilayas, and by Laghouat, Ghardaïa, Adrar to the east and south-east. To the west and south-west by the provinces of Sidi Bel Abbes, Naama and Béchar (Directorate of Planning and Territorial Development, 2010).

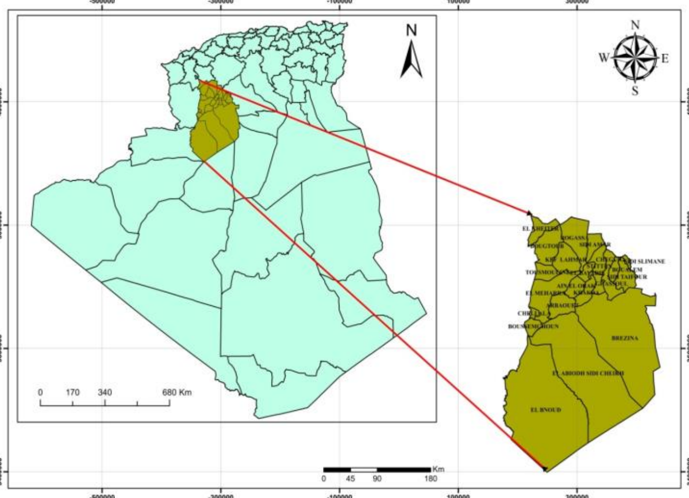

Figure 1. Geographic location map of the Wilaya of El Bayadh

According to National agency for territorial planning (2003), the territory of the province is divided into three main areas:

- The high steppe plains to the north account for "22%" of the province's total surface area. These high plains include 6 communes: Bougtoub, El Kheiter, Tousmouline, Rogassa, Kef L'Ahmar, Cheguig and part of Mehara (National agency for investment development, 2013).
- The Saharan atlas in the center represents 18% of the total surface area and is the most populated entity ("50%" of the total population). Composed of 13 communes (El Bayad)
- Boualem - Sidi Amar - Sidi Taiffour -Sidi Slimane Stitten - Ghassoul - Krakda - Ain El Orak
- Arbaouet -Chellala -Mehara, Boussemghoun) (National agency for investment development, 2013).
- The pre-Saharan zone: This zone accounts for 60% of the province's total surface area, or 5.107.270 ha. It comprises three communes: Brezina, El Abiod Sid Cheikh, Bnoud (Directorate of Planning and Territorial Development, 2010).

2.1.1 Location of the study area

Our study area is located in the north of the province of El Bayadh, in the high plains region, and comprises three communes: Bougtoub, Tousmouline and El Kef-Lahmar (Figure 2).

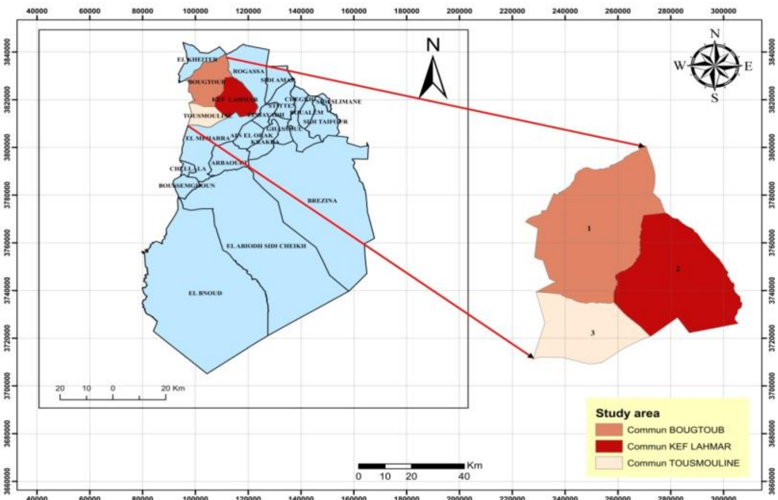

Figure 2. Location map of the study area

Table 1. Surface area of the three study communes

Municipality	Area (ha)
Bougtoub	201760
El Kef-lahmar	162240
Tousmouline	88110

The selection of this area was based on a series of criteria:

- The area is part of Algeria's high steppe plains, which constitute a barrier to the movement of sand from south to north.
- The fragility of the steppe ecosystem and its exposure to desertification.
- The noticeable change in the vegetation cover, which is a regressive dynamic of steppe vegetation with the formation of sand deposits in the study area.
- The notable change in land use in this area over time. Mainly parkland.

2.2 Factors favouring desertification in Algerian steppe areas

2.2.1 Factors linked to human activity

2.2.1.1 Overgrazing

Defined by (Le Houérou, 1995) as the removal of a quantity of vegetation greater than the annual production of the rangelands, overgrazing is the result of overloading a given area with a large number of livestock This action induced physiognomic and landscape changes which are at the origin of long-term dynamics and major changes in the region's resources (Le Houérou, 2009; Negm et al., 2020). Livestock farming plays an important role in the economic life of the steppe region. Red meat production in Algeria primarily originates from sheep farming (56%) and cattle farming (34%), while goat and camel farming contribute 8% and 2%, respectively. Sheep farming is a key national asset due to its livestock population and breed diversity. Official data indicates that in 2017, Algeria had 26 million sheep and produced 325,000 tons of sheep meat. The sheep farming sector has shown consistent growth in recent years, increasing from 1,800 quintals in 2005 to nearly 2,700 quintals in 2017, representing a 44.5% rise. Approximately 7.5 million locally raised sheep are slaughtered for meat, accounting for 150,000 Tons Equivalent Carcass. (Zemour, 2020).

2.2.1.2 Demographic growth

Algeria's population reached 42.4 million in 2018. A population growth rate of "2.1%" indicates that Algeria is no longer in a phase of demographic transition. The urbanization rate is "72%", and the rural population is now falling even in absolute terms "-0.4%" year) (Bessaoud et al. 2019). This demographic growth is leading to the overexploitation of natural resources by the Algerian population to cover its needs.

2.2.1.3 Rangeland clearing and farming activities

The natural factors behind the degradation of steppe rangelands are linked to the fragility of the ecosystem in these areas. Climatic and edaphic factors can also cause steppe degradation, the latter accentuated by the phenomenon of erosion (Le Houerou, 1995). These degradation conditions favor the establishment of plants of low forage value that do not meet the needs of the animal load, but rather this accentuates the pressure of overgrazing on non-degraded areas (Hasnaoui & Bouazza, 2015; Merdas et al., 2021).

2.2.1.4 Climate

Climate change, marked in Algeria by higher average temperatures and lower rainfall, is having an impact not only on the quality and resilience of ecosystems (Bessaoud, et al., 2019), but also on the Algerian steppe, which is experiencing long dry seasons due to the rise in average temperatures and low rainfall, as confirmed by several weather stations in the Algerian steppe over the past 50 years (Figure 3).

2.2.1.5 Erosion

The intense impact of climatic events and the fragility of the plant cover to protect the soil help to increase the risk of wind and water erosion in the arid steppe (Habib, 2004). The climatic conditions of the last decades, characterized by long periods of intense drought (Belala et al. 2018; Kouba et al. 2021; Zemour, 2022), have been at the origin of the degradation of the vegetation cover of steppe formations dominated by *M. tenacissima, Atriplex halimus,* and *Artemisia herba-alba,*

2.2.1.6 Soil salinity

Over "95%" of soils in arid regions are either calcareous, gypsiferous or sal sodic (Halitim 1988). High temperatures over a long period of the year cause high evaporation rates for rainwater after infiltration.

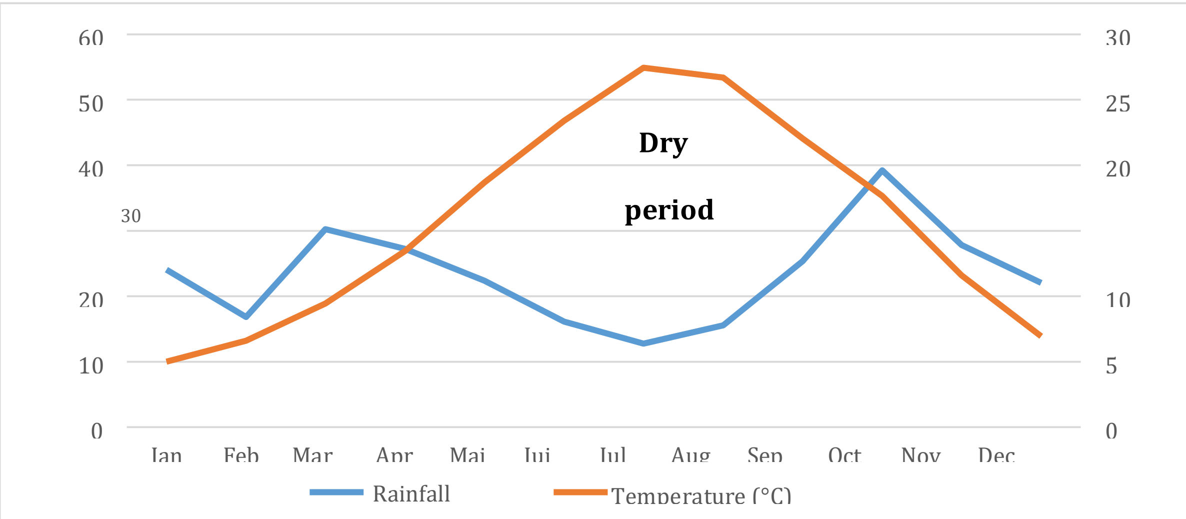

Figure 3. Bagnouls and Gaussen diagram for the El Bayadh meteorological station for the period (1988/2018) Source :(Youssoufa , 2020)

2.3 The impact of desertification on the Algerian steppe ecosystem

Due to drought, desertification and, in particular, inadequate management, the natural regeneration of esparto grass is compromised. Since 1984, esparto production has been steadily declining. In 1990, esparto production stood at just 4.000 tonnes, compared with 36.588 tonnes in 1984. Steppe rangelands are in an advanced state of degradation, with 7 million hectares threatened by desertification. Steppe degradation has major socio-economic repercussions, including reduced forage availability, precarious sheep farming, silting up of urban areas and roads, and disruption of the balance of the traditional pastoral organization system (Benderradji et al. 2006). Land degradation and desertification at its most advanced stage, leading to loss of biological potential and disruption of socio-economic equilibrium (Nedjraoui & Bédrani, 2008).

2.4. *Creating the various GIS information layers*

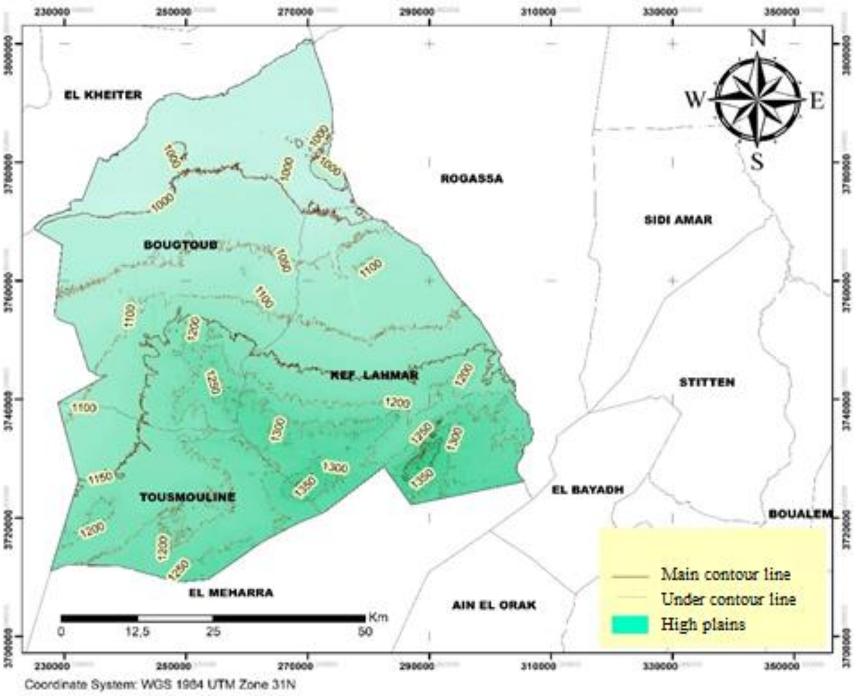

Figure 4. Topographical map of the study area

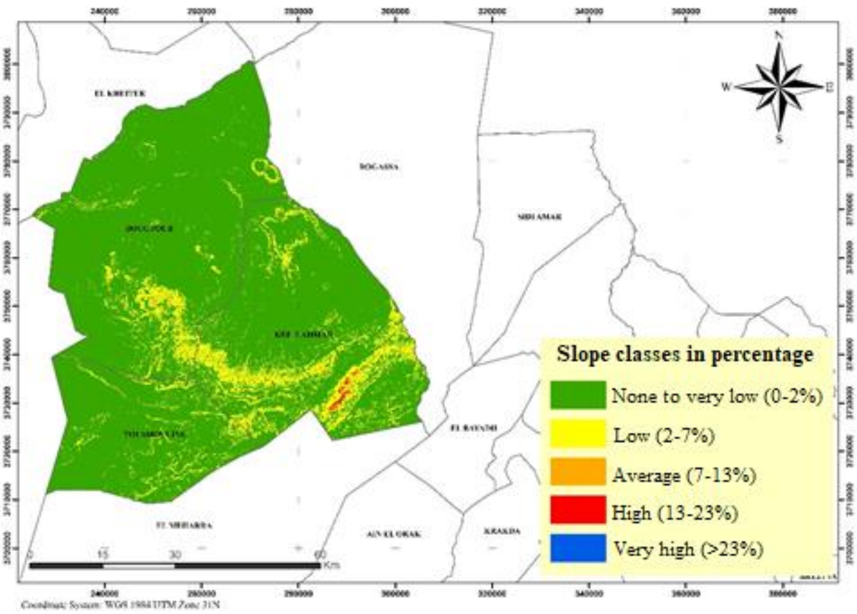

Figure 5. Slope map of the study area

The topographic map of the study area (Figure 4) shows that the contour interval in our study area is small, which means that the area from the main contour line 1000 to 1240 is a low-lying zone. In other words, our study area is dominated by the high plain. The topographic map also shows a grouping of contour lines in the Kef l'Ahmar area, indicating the presence of a low, rocky elevation.

The result obtained from the slope map (Figure 5) for the study area shows that slope values are divided into five slope classes, ranging from "0%" to over "23%". The slope classes are distributed as follows:

Table 2. Surface area of slope classes in the study area

Slope class	Intervals	Area in ha	Percentage
None to very slight	0% et 2%	396959,44	88.4%
Low	2% et 7%	50566,78	11,26 %
Medium	7% et13%	1069,29	0,23%
High	13% et 23%	414,27	0,09%
Very high	More than 23%	25,14	0,005%

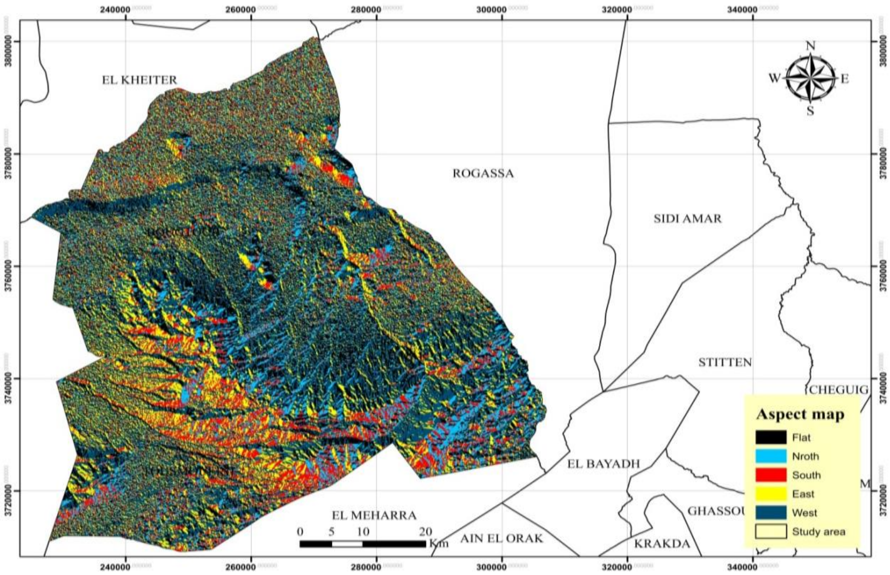

Figure 6. Exposure map of the study area

The exposure map of the study area reveals four distinct exposure classes: flat, north, east, south, and west. Among these, the west exposure class is the most predominant, covering 28% of the total surface area. The flat exposure class follows, accounting for 25% of the area. The eastern exposure constitutes 17% of the study zone, while the northern exposure represents 16%. Lastly, the southern exposure covers 14% of the total surface area. This distribution highlights the dominance of the west-facing terrain and the relatively balanced representation of the other exposure classes.

Table 3. Exposure areas in the study zone

Exposure classes	Area (ha)
East	75316
Flat	113873
North	69631
South	64677
West	125572
Total	449069

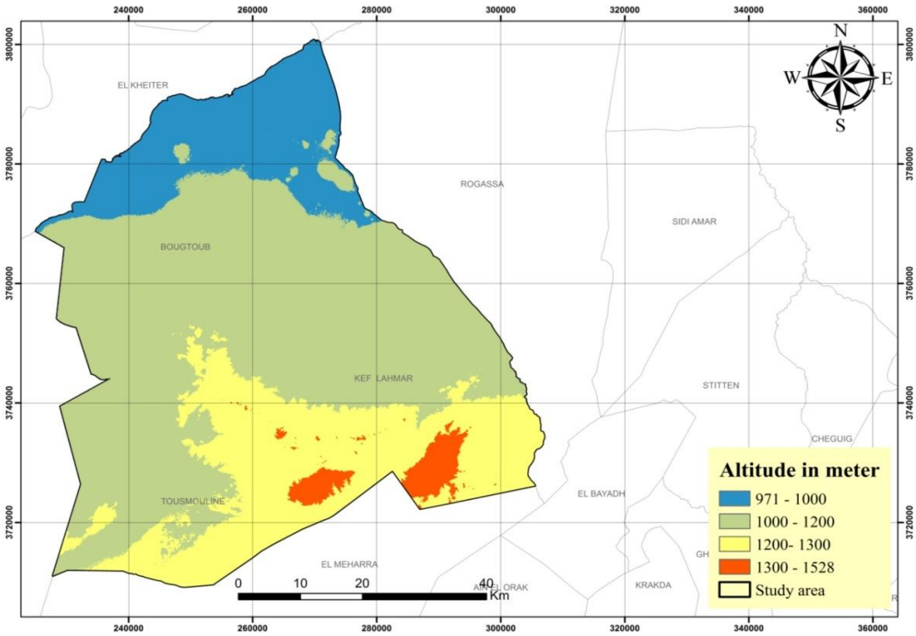

Figure 7. Hypsometric map of the study area

The altitude of our study area ranges from (971m to 1528m), with the altitude classes distributed as follows:

- Altitude class (971- 1000m) covers "14.75%" of the total area.
- The altitude class (1000-12000m) is the most dominant, occupying "58.57%" of the total area.
- The altitude class (1200-1300 m) occupies "24.09%" of the zone's total surface area.
- The altitude class (1300-1528 m) occupies "2.57%" of the zone's total area.

Table 4. Area of altitude classes in the study area.

Altitude Class	Area in ha
Altitude Class (971-1000m)	661
Altitude Class (1000-1200m)	2629
Altitude Class (1200-1300m)	1083
Altitude Class (1300-1528m)	11566

3. Results and discussion

3.1 Calculation of NDVI at different dates (1990, 2010 and 2022)

To carry out our study, we calculated NDVI for each year, i.e. a supervised color classification based on this index. NDVI is a robust predictor for quantifying vegetation growth variations in arid and semi-arid areas (Belmahi, 2014; Derdour et al., 2022). The results of our calculation are shown in the figures below.

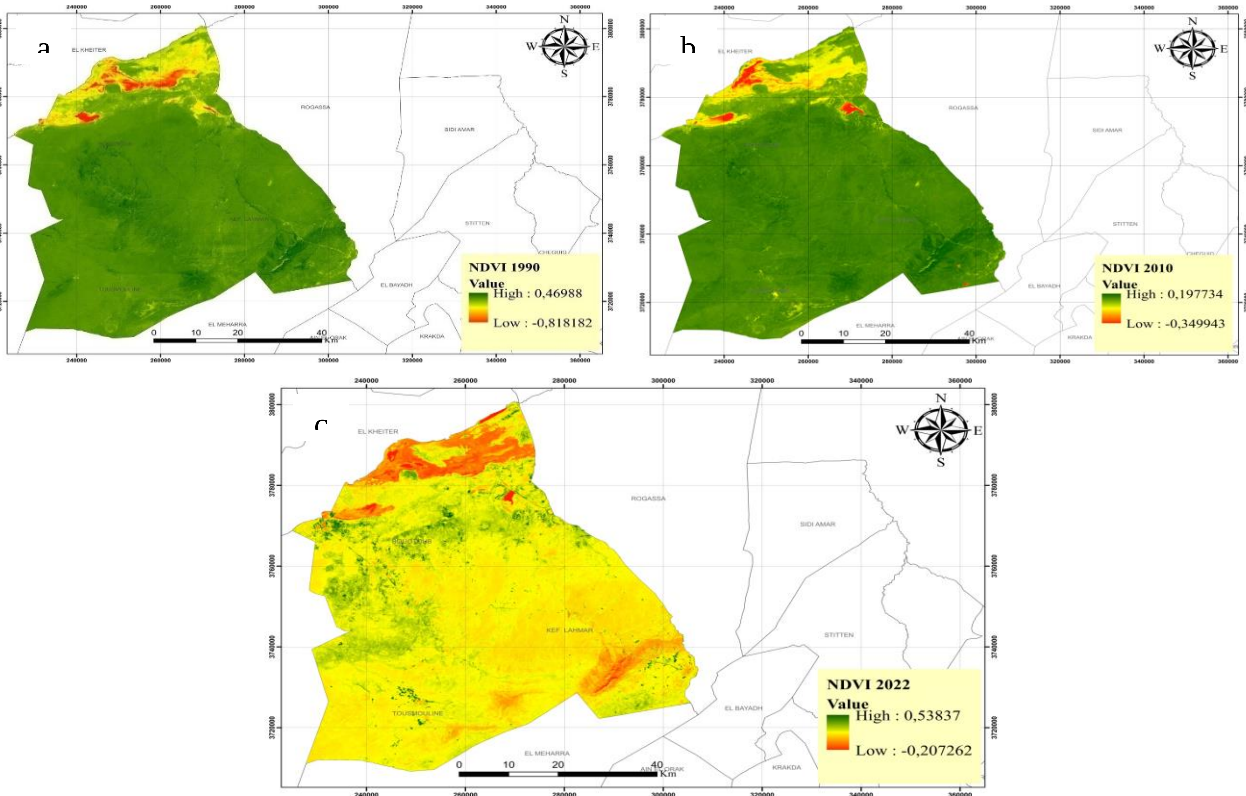

Figure 8. Vegetation index map of the study area years (a: 1990; b: 2010; c: 2022)

Our NDVI values are classified into three categories: None, Medium and High. The NDVI values of our study area for the years 1990 and 2010 are well specified between (0.469 and -0.818 for 1990 and between 0.197 and -0.349 for 2010). Areas classified with the red color indicate the lowest NDVI values and less than 0, which clearly shows us that chlorophyll activity is nil and also values close to -1 which correspond to sebkha water located to the north of the study area in the commune of Bougtoub. Zones classified as yellow indicate areas with average chlorophyll activity. Zones classified as green indicate areas with the highest chlorophyll activity, occupying most of the surface area of our study zone.

It can be seen that there is no significant difference in the classification results between the two years 1990 and 2010. Among other things, the NDVI map for the year 2022 in the study area gives values between (0.538 and -0.207). There has been an enormous change in the yellow and red categories, and a decrease in the green category compared with previous years, which is a sign of vegetation degradation, especially in the south-east of the study area.

3.2 Evolution of vegetation between (1990 and 2022)

To determine the evolution of vegetation cover during the period of our study, we cross-referenced the two maps obtained by supervised classification of NDVI for 1990 and 2022, using spatial analysis techniques.

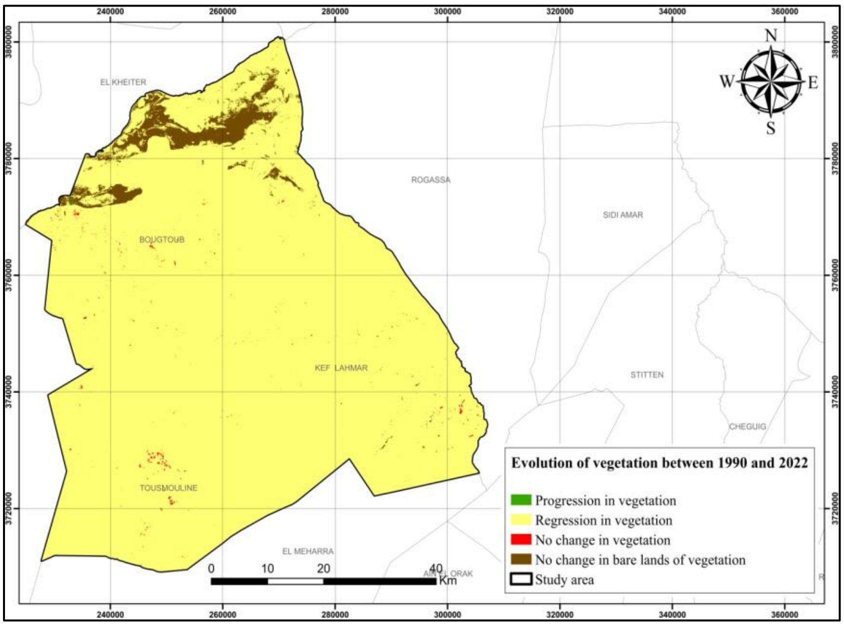

Figure 9. Map of vegetation evolution in the study area between 1990 and 2022

A significant change in vegetation cover has been noted since 1990, As the area has experienced severe vegetation regression affecting most of the surface area of the three communes Bougtoub Tousmouline and Kaf lahmar, this class of vegetation cover regression occupies "96%" of the total surface area of 432164.53 ha.

Overexploitation of pastoral resources and overgrazing are among the main causes of plant cover degradation in these steppe zones, leading to a decline in perennial plant cover and esparto phytomass, which fell on average from 2,000 kg/ha in 1975 to 600 kg/ha in 2000 (Benaradj, Mederbal et al., 2010; Moulay, 2013; Bensmira et al., 2015) and increasingly uncertain climatic context (Poletti, 2018), and so the Stipa tenacissima steppe is in an advanced state of degradation facilitating the desertification process (Moulay, 2013).

It was noted that vegetation growth is very low and almost non-existent at "0.01%" of the total surface area, i.e. 62.15 ha, most of which is located in areas of human activity, such as agriculture and reforestation. Generally this limited progression is due to climatic conditions: low rainfall and long dry seasons.

The remaining "3.75%" of the land area, i.e. 16866 ha, has not changed over the 32-year period and is divided into two categories: land that remains bare or occupied by water (sebkha), estimated at 15883.5 ha, and land that represents no change in vegetation, estimated at 983.337 ha.

Table 7. Land area after vegetation change

Class	Area (ha)
Vegetation progress	62,1511 (0%)
Vegetation regression	432164,53 (96%)
No change in vegetation	983,337 (4%)
No change in barren of vegetation	15883,512 (0%)

3.3 Land use maps

A diachronic analysis was performed to track the spatiotemporal evolution and dynamics of land cover in the study area and highlight the magnitude of changes in vegetation cover between 2010 and 2022. This study's methodology is a geomatic approach to geographic information extraction based on supervised classification. According the author (Bouarfa et al., 2022), supervised classification is the most commonly used image processing method for land cover in arid to semi-arid regions. This operation groups pixels based on spectral similarity while adhering to the analyst's thresholds. It intends to use remote sensing and GIS to quantify the vegetation recovery rate and map the state of the steppe rangelands (Naziha et al., 2023).

Land cover was obtained from a supervised classification of satellite images from 1990, 2010 and 2022 by taking samples from 7 classes: sandy areas, steppe soils, vegetation, Chott, hydromorphic soils, rocky outcrops and built-up areas. The results are shown in Figures 11, 12, and 13.

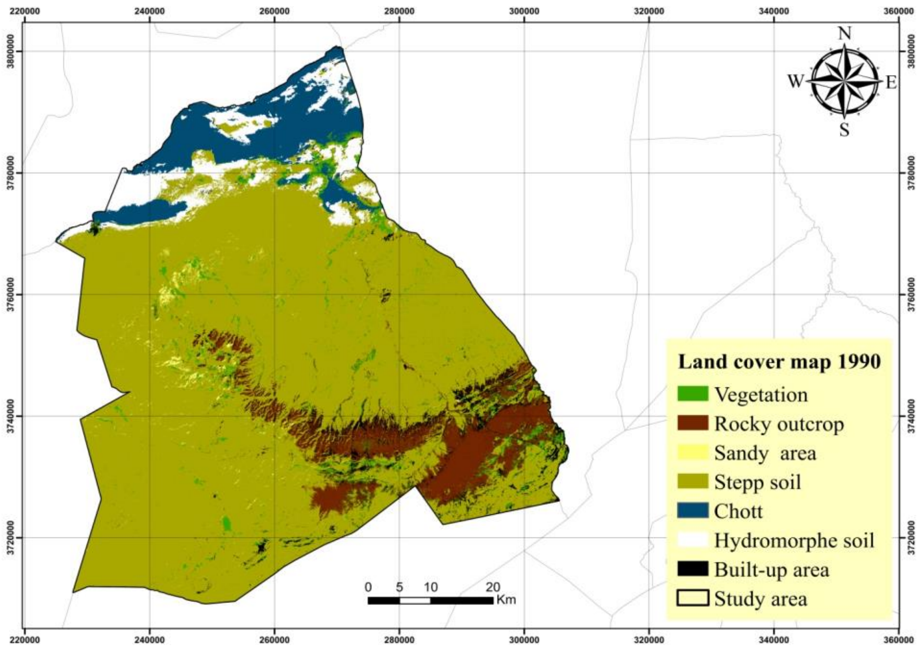

Figure 10. 1990 land use map of the study area

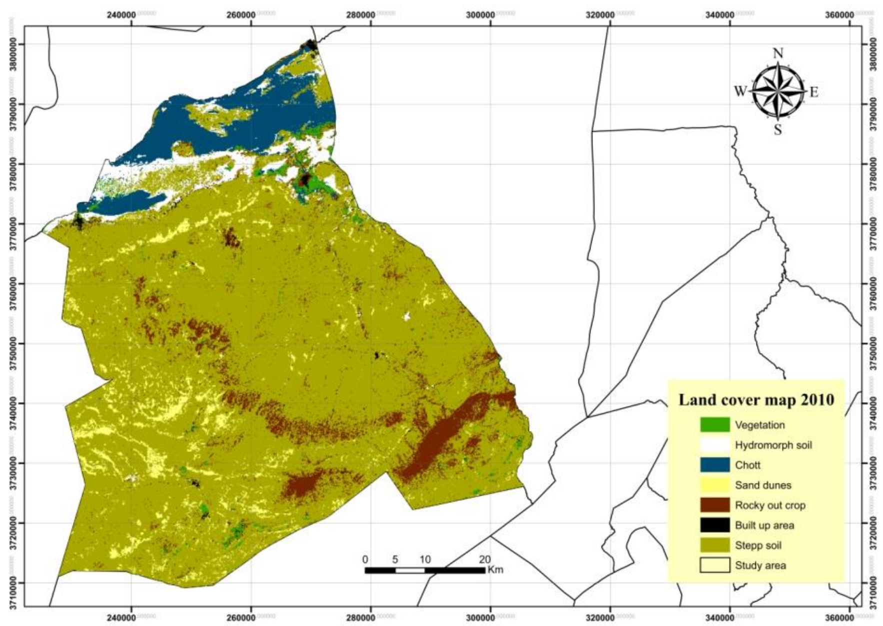

Figure 11. 2010 land use map of the study area

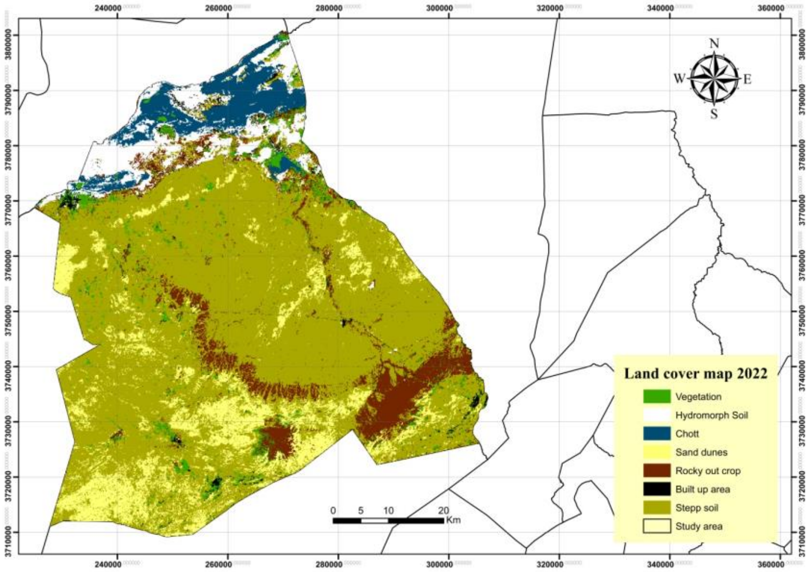

Figure 12. Land use map of the study area year 2022

After analyzing the results of the classification of the land use maps in 1990, 2010 and 2022, we found that in 1990, steppe soils classified by the olive green color occupy most of the land, with a surface area of 295610.13 ha, i.e. "66%" of the total surface area of the study area. The "34%" represents the other classes (sandy areas, vegetation, Chott, Hydromorphic soils, rocky outcrops and built-up areas), or the class of sandy areas classified by the color yellow, occupying around 3235.5 ha of the total surface area of the study area, most of which is located in the southern part of the Bougtoub commune.

Some areas that used to have steppe soils turned into areas mostly made up of sand dunes in 2010, covering 20,132.82 hectares, or 4% of the total area. This shows how land use changed from 1990 to 2010. The dunes present in 1990 just within the commune of Bougtoub emerged in the western and southern peripheries of the research area encompassing the communes of Tousmouline and Bougtoub.The analysis of the land use map for 2022 indicates that since 1990, the category of sandy areas has had significant growth, totaling 57,817.8 hectares, which is 16% of the overall surface area in 2022.The emergence of the sand class affects areas that were silted up in 2010 and areas that were named steppe soils in both 2010 and 1990. This causes desertification in these steppe zones. Sand is prevalent in all three communes, but it is more pronounced in the commune of Tousmouline and the western region of Bougtoub..Land use has stayed mostly the same since 1990 for the other classes (steppe soils, vegetation, chott, hydromorphic soils, rocky outcrops, and built-up areas). The only change is that the percentage of water (sebkha) in Bougtoub has gone down and the number of built-up areas has gone up, mostly in the main towns of the three study communes because of urbanization.

Table 8. Surface area of land use classes

Class	Area (ha) 1990	Area (ha) 2010	Area (ha) 2022
Built up area	2369,34	4479,21	4570,02
Chott	29625,93	30529,44	23445,9
Hydromorphe soil	26197,38	17622,27	28535,31
Out crop rocky	83673,27	32798,7	37821,06
Sandy area	3235,5	20132,82	57817,8
Steppe coures	295610,13	339311,43	280334,34
Vegetation	6203,61	6362,1	16713,54

3.4 Regression and progression maps of land use classes

The information presented by the three land cover maps has enabled us to observe some very important results concerning the evolution of desertification in the study area over a 32-year period. We have cross-referenced the land cover maps for the three years (1990-2010) and (2010-2022) and (1990-2022) to obtain maps of the regression, progression and stability of each land cover class.

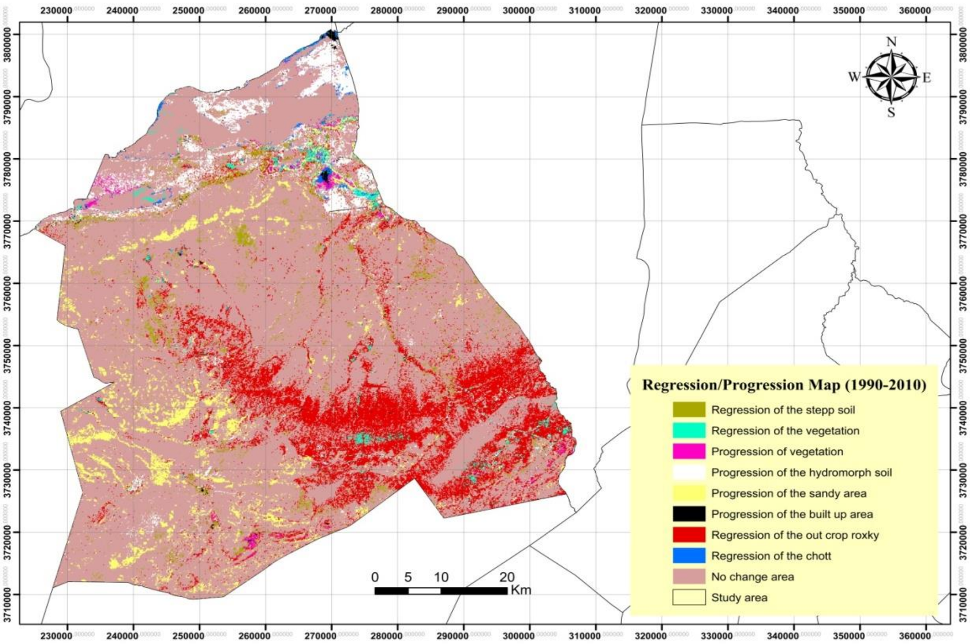

Figure 13. Land use class progression/regression map between 1990 and 2010

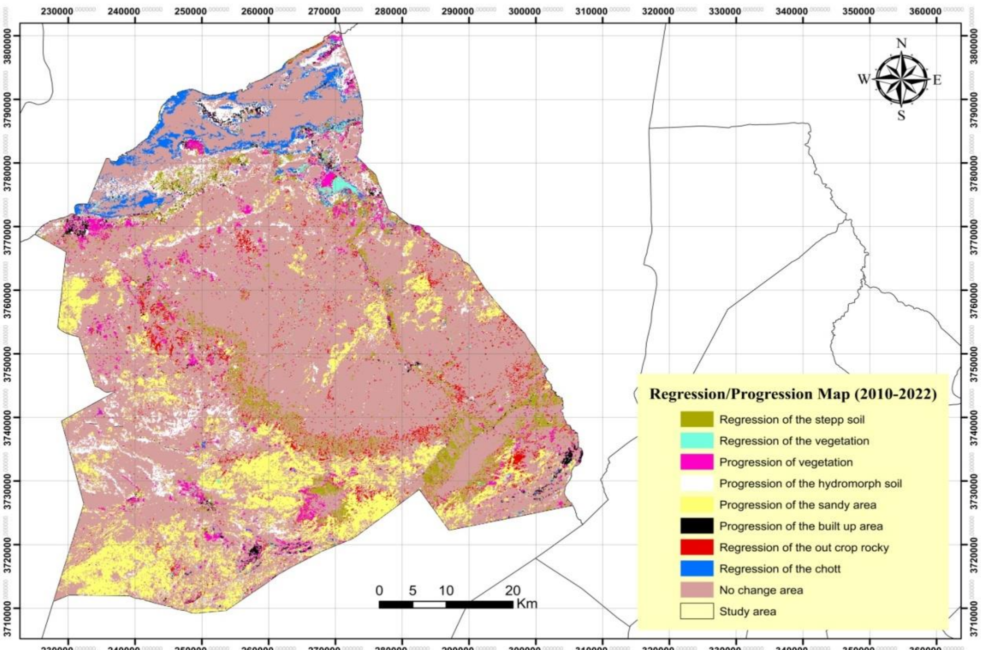

Figure 14. Progression and regression of land use classes between 2010 and 2022

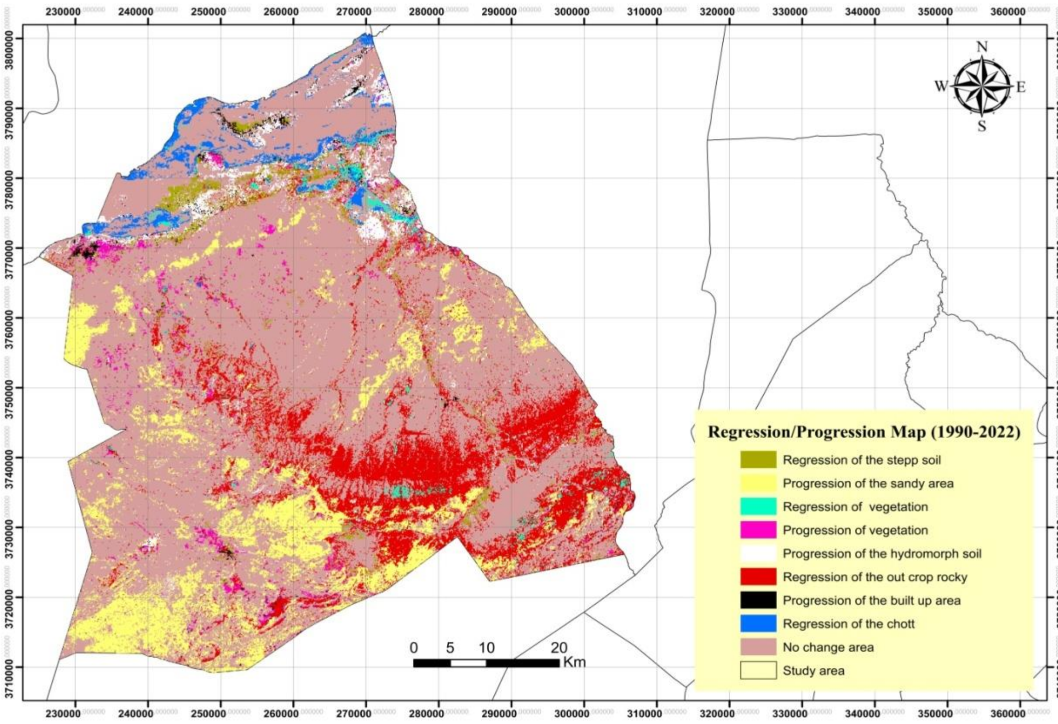

Figure 15. Map of progression/regression of land use classes between 1990 and 2022

Interpretation of these three maps shows that our study area is subject to a serious progression of sanded areas affecting the entire study area. This progression is estimated at 38678 ha of the total area during our study period between the years 1990 and 2022. According to the results of the classification, the surface area of sandy land in the study area in 1990 was 3235.5 ha, around 1%, and will reach 57817.8 ha, or "13%" of the total surface area in 2022, bearing in mind that the increase in sandy areas during the study period mainly includes the western and southern regions, where the communes of Tousmouline and Bougtoub are located.

According to the study by (Bouiadjra et al. 2010) entitled Spatio-temporal analysis of the phenomenon of desertification in the three study communes, the surface area of sandy land in the three communes of Tousmouline El kaf-lahmar Bougtoub was 20105.09 ha in 2001. We can observe that there is a regression in the Chott class due to water evaporation (sebkha) in Bougtoub. This regression is estimated at 15210 ha of the total surface area between 1990 and 2022. There is also a progression in the class of hydromorphic soils, estimated at 12215 ha of the total surface area between the same study period. These hydromorphic soils are formed on the edge of the Bougtoub sebkha.

The vegetation class underwent an estimated progression of 15800 ha and an overall regression of 7176 ha over the 32-year interval. The progression of vegetation includes areas with high population density and human activities such as agriculture and reforestation within each of the communes of Bougtoub and Tousmouline, with little development of halophytes next to the Bougtoub sebkha. Finally, the class of zones under construction has grown by an estimated 9,000 ha, centralized in the main towns of the three communes: Bougtoub, Tousmouline and Kaf lahmar.

Table 9. Progression/regression areas of land use classes between 1990 and 2022

Progression/regression des classes	Area ha
Progression of the sandy area	38678
Regression of the Stepp cours	11228
Progression of vegetation	15800
Regression of the vegetation	7176
Progression of the Hydromorph soil	10740
Progression of the built up area	9000
No change area	299904
Regression of the out crop rocky	20000
Regression of the chott	15210

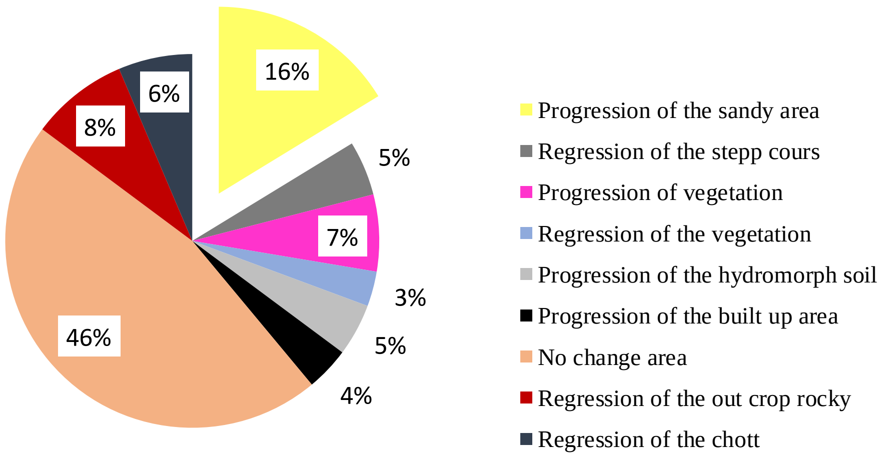

Figure 16. Progression/regression of land use classes between 1990 and 2000

3.5 Final change map

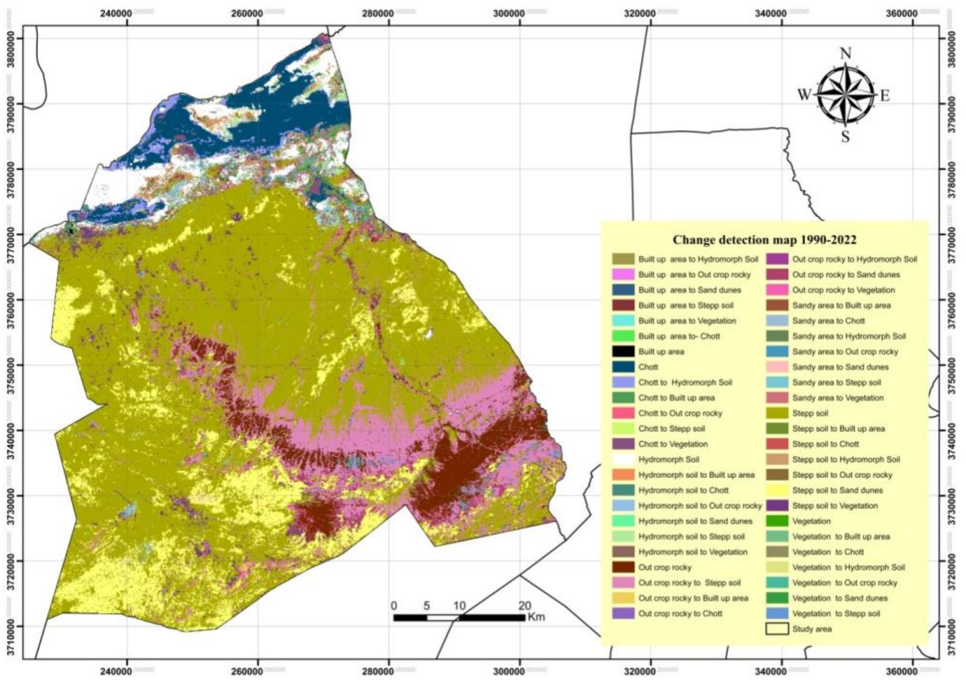

Figure 17. Map of final land-use change (1990-2022)

The map of the final change in land use between 1990 and 2022 shows that the land where silting has worsened has mainly affected steppe soils devoid of plants that survive on the earth's surface, such as steppe vegetation resistant to specific climatic and edaphic conditions, such as : alfa (*Stipa tenacissima*), Sennagh (*Lygeum spartum*), Chih (*Artimisea herba alba*) , and *Aristida pungens* (Drinn). Steppe vegetation is in a state of decline due to over-exploitation by humankind, leading to silting and desertification. Since grazing is the most important economic activity in steppe areas, overgrazing is a major cause of the deterioration of pastoral resources.

Table 10. Area of land use change

Change of land use	Area (ha)
No change in chott	21864,15
Chott to Vegetation	1296,18
Chott to Hydromorphe Soil	5227,74
Chott to Built up area	314,91
Chott to Stepp Cours	288,45
Hydromorphe soil to Chott	809,73
Hydromorphe soil to Vegetation	1183,95
No change Hydromorphe Soil	17105,76
Hydromorphe soil to Built up area	1055,97
Hydromorphe soil to Stepp Cours	3430,62
Hydromorphe soil to Sand dunes	34,02
Sandy area to Vegetation	157,95
Sandy area to Hydromorphe Soil	774,36
Sandy area to Built up area	26,37
Sandy area to Stepp Cours	1262,88
No change in sand dunes	652,59
Out crop rocky to Vegetation	4167,63
Out crop rocky to Hydromorphe Soil	739,17
Out crop rocky to Built up area	1083,6
No change in Out crop rocky	25348,86
Out crop rocky to Stepp Cours	46867,5
Out crop rocky to Sand dunes	5383,71
No change in Vegetation	1605,96
Vegetation to Hydromorphe Soil	444,6
Vegetation to Built up area	203,85
Vegetation to Out crop rocky	1183,32
Vegetation to Sand dunes	138,78
Stepp cours to Hydromorphe Soil	3124,98
Stepp cours to Built up area	1412,19
No change in Stepp Cours	224495,28
Stepp cours to Sand dunes	51319,53
Built up area to Vegetation	607,77
No change in Built up area	371,07
Built up area to Sand dunes	188,73

4. Conclusion

The study of land use in Algeria's steppic zones was carried out using a diachronic approach based on multi-date satellite images (1990, 2010 and 2022) from Landsat's Thematic Mapper sensor, combined with remote sensing and GIS. Satellite imagery has proved to be an ideal tool for detecting and monitoring certain environmental phenomena and changes likely to affect the equilibrium of ecosystems, enabling decision-makers to respond to the incessant need for permanent, credible information within the shortest possible timeframe. Remote sensing is a means of inventorying, monitoring and managing natural resources, and of establishing development scenarios. It minimizes costs and extends the spatial and temporal scope of conventional methods. The results obtained from the mapping of silting in the study area between 1990 and 2022 show an amplification of silting since 1990, with 3235.5 hectares or around 1%, while the surface area of silted terrains reached 57817.8 ha in 2022, or "13%" of the total surface area. The main affected regions are the west and south of the study area, where the commune of Tousmouline and the commune of Bougtoub are located.

Authors' declaration and contribution

The authors declare no conflicts of interest. The contributions of authors across all stages of this research article were varied and essential, including concept generation, methodological enhancement, data collecting, analysis, manuscript preparation, critical evaluation, project oversight, and underscoring a thorough joint effort.

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