

Spatial dynamics of land degradation in Algeria's central high plateaus and the green dam belt using sentinel-2 imagery

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Abstract:

The Central high plateaus of Algeria represent a critical pastoral ecosystem currently threatened by accelerating land degradation. This study investigates the spatial dynamics of land degradation from 2000 to 2025, a period marked by significant climatic shifts and socio-economic pressures. Utilizing multi-sensor satellite imagery (Sentinel-2) alongside climate data, we employed the Albedo-NDVI feature space models and the Desertification Vulnerability Index (DVI). Overgrazing intensity was quantified by analyzing the deviation between potential and Land Degradation Index (LDI). Preliminary findings indicate a systematic expansion of degraded areas, with a 15% increase in high-severity desertification zones. A strong spatial correlation was observed between livestock density peaks and vegetation browning trends, particularly in the steppic transitions. While cyclical droughts exacerbated soil erosion and Sand Encroachment, overgrazing was also identified as the primary driver of irreversible botanical composition changes. The findings provide a high-resolution mapping of environmental vulnerability, offering a robust diagnostic tool for regional policymakers. This research underscores the urgent need for adaptive rangeland management strategies to mitigate the dual impact of anthropogenic pressure and climate change in the drylands of Algeria.

1. Introduction

Land degradation forms a phenomenon one of the most critical environmental challenges in Algeria, particularly in arid and semi-arid regions characterized by fragile ecological systems and increasing exposure to climatic variability and anthropogenic pressures. Within this regional context, Algeria is among the most affected countries, especially in its steppe and semi-desert zones, where recurrent droughts, rainfall variability, overgrazing, and unsustainable land-use practices have led to progressive deterioration of soil quality, vegetation, and overall ecosystem productivity. The Algerian central High Plateaus constitute a major ecological unit in North Africa,

and serve as a transitional zone between the northern Tellian Atlas and the southern Saharan domain. This vast plateaus region is characterized by semi-arid to arid climatic conditions and a pastoral land-use system that relies heavily on natural pastures. However, this area has experienced significant environmental stress, reflected in vegetation decline, soil erosion, and the expansion of desertification processes. These dynamics are driven by the combined effects of climatic constraints and human activities, particularly overgrazing and unsustainable exploitation of natural resources.

In this context, the Algerian Green Dam is considered one of the major environmental projects established in 1971, acting as a protective barrier

to reduce the northward expansion of desertification. The Green Dam extends across the steppe zones of Algeria from west to east. It aims to stabilize fragile soils, restore vegetation cover, and mitigate desertification processes. Despite continuous reforestation and conservation efforts, several parts of the Green Dam Belt continue to exhibit varying degrees of degradation, highlighting the need for systematic spatial monitoring and assessment.

Given the importance of using modern geospatial technologies, particularly remote sensing, in the ability to monitor and analyze land degradation processes over large and high-precision spatial scales. It has therefore become essential to rely on Sentinel-2 satellite imagery, which provides high spatial and spectral resolution data, allowing the monitoring of vegetation dynamics and the assessment of land degradation conditions. Accordingly, this type of data was selected, as it is particularly suitable for this study focusing on the spatial dynamics of land degradation at the level of the semi-arid regions as is the case in the Central High Plateaus of Algeria, which represent an environmentally sensitive area characterized by rapid changes and high vulnerability to desertification and soil degradation.

This study aims to analyze the spatial dynamics of land degradation in Algeria's Central High Plateaus and the Green Dam Belt using Sentinel-2 imagery. The study focuses on identifying spatial patterns of degradation, as well as mapping the spatial extent of degraded areas and analyzing spatial variations in order to understand and identify changes in vegetation cover and the lands that have been increasingly affected by desertification in the Central High Plateaus, including the Green Dam perimeter within the study area. Accordingly, this study aims to contribute to the identification of degraded lands within the Central High Plateaus and the Green Dam belt, in order to mitigate overgrazing and sand encroachment. It also seeks to produce meaningful results that may support recommendations for the revitalization of the Green Dam project, with the aim of preserving ecological balance, combating desertification, and promoting sustainable environmental development in Algeria. Based on the above considerations, the research problem of this study is formulated and structured around the following questions:

- What are the manifestations of land degradation Central High Plateaus and the Green Dam belt in Algeria?
 - Is land degradation in Algeria's Central High Plateaus primarily associated with climate change and drought, or with the impacts of

overgrazing on natural rangelands and the Green Dam belt? What is the effectiveness of using Sentinel-2 satellite imagery in monitoring and analyzing land degradation in the study area? To address the research problem raised in this study, we followed a methodological framework consisting of the following elements:

2. Material and methods

This study adopts a descriptive and quantitative analytical approach to investigate land degradation dynamics in Algeria's Central high plateaus and the Green Dam belt using Sentinel-2 imagery. Official data were collected from the National Office of Statistics (NOS), the High Commission for the Development of the Steppe (HCDS), forest and agricultural services, in addition to previous scientific studies.

Spatial and statistical analyses were performed using ArcGIS 10.8, ENVI 5.6, and Google Earth Engine (GEE). Vegetation and land degradation were assessed through the calculation of the Normalized Difference Vegetation Index (NDVI), Net Primary Productivity (NPP), Land Degradation Index (LDI), and Desertification Vulnerability Index (DVI) derived from Sentinel-2 data. The results were represented using statistical tables, thematic maps, and graphical figures, supported by field observations to improve the accuracy of the analysis.

3. Study area

3.1. Geographical location of the study area

The study area is located in northern Algeria within the Central High Plateaus, which represent a transitional ecological zone between the Tellian Atlas in the north and the Saharan Atlas in the south. Administratively, the study area includes three major provinces: Djelfa, Laghouat, and M'sila, which are among the most important steppe provinces of the central high plateaus (Fig.1). Geographically, the area extends approximately between 33°30'N and 35°00'N latitude and 2°30'E and 5°30'E longitude (Fig.1). This location places the region within a semi-arid climatic zone characterized by continental conditions, where rainfall is low and irregular, while evaporation rates are high. Consequently, the region is highly vulnerable to land degradation processes such as desertification and overgrazing. The three provinces cover extensive steppe areas that form a key component of the Central high plateaus ecosystem. Situated within the Central High Plateaus, the provinces of "M'Sila, Djelfa, and Laghouat"

collectively encompass an extensive portion of the Algerian high plateaus region, covering a total pastoral area estimated at 5.044.460 hectares, representing about 24.34% of the total High Plateaus area in northern Algeria. Whereas it occupies a vast area within the Algerian high plateaus region, extending approximately 550 km from east to west and about 450 km from north to south, from the borders of Sétif Province in the north to the borders of Ghardaïa Province in the south, as shown in map (Fig.1). Within the total area of the High Plateaus surface distributed across 19 provinces covering an area of 20.724.048 ha, as these provinces collectively constitute a vast steppe pastoral ecological region (Table.1).

The GREEN DAM also represents an integral part of the study area, it is a vegetated green belt that stretches across the High Plateaus, separating them from the Saharan Atlas. Covering an area of approximately 4.7 million hectares, stretching over a distance of 1500 km long and 20 kilometers wide, representing more than 18% of the steppe region across 13 high plateaus provinces (Bahri, 2025). More than half of this area consists of pastures lands, while forested areas account for 18% which corresponds to an area of 665741 hectares (Chaifa, 2025). According to the plan of the current president of Algeria Abdelmadjid Tebboune, reviving this project requires a comprehensive program, including afforestation operations covering more than 17000 hectares over a 10-year period (2020-2030). This green belt constitutes one of the effective mechanisms among various projects primarily aimed at protecting the steppe environment and combat desertification through afforestation in order on one hand, and to increase vegetation on the other. Thinking about the GREEN DAM project in Algeria began in 1967 as a result of the encroachment of sand from south to north and the increasing degradation of steppe lands, and in 1971 President Houari Boumedienne launched the project, as he mobilized more than 20,000 soldiers from the People's National Army, in addition to volunteering civil society organizations as part of the steppe development program (Sakhri, 2024). Its goal is to establish a green vegetative strip of pinus pinea trees forming a belt stretching from west to east along the contact zone between the desert and the high plateaus, extends over a distance of 1500 km and an area of three million hectares (Rahmani, 2021). see following (fig.2).

Geographical characteristics and climatic conditions of the study area

The predominant morphological feature of the study area is that they are high plateaus formed as a result

of the recent folding and twisting processes that affected the Algerian hill region interspersed with faults that struck the region during the period in which the Atlas Mountains were subjected to twisting. These are the same geological movements that affected the Alps mountains during the Tertiary geological period (Halimi, 1968). However, they are primary for salt extraction as is the case with chott El-Hodna which lies 400 m above sea level and is located about 20 km south of M'sila city in the eastern high plateaus and chott Melghig (Rahli, 2018). which lies at (-32m) below sea level and is surrounded by many salt flats in El-Ouadi city about 150 km south of the chott.

Where the annual rainfall in the northern part is 400 mm/year and the Saharan Atlas Mountains in the south does not exceed 100 mm/yrs (Ghazal, 2019). In addition, the decline of natural and biological processes limits the growth and Low vegetation density, while intensifying geomorphological processes such as the action of dry winds and soil erosion caused by internally drained watercourses. A vast pastoral area in the middle of the high plateaus, whose lands range in elevation from 900 to 1000 metres (HDCS, 2010). All these factors gave rise to a continental environment dominated by a semi-arid climate, what distinguishes this region of high plateaus is the presence of a long hot and dry season that lasts for seven full months, during which rainfall drops to 4 mm and the temperature rises to exceed C °40, like July, and a short, cold season with little rain not exceeding 65 mm, and the average temperature is only C °7 as of January (fig.3).

4. Results

4.1. Physical environment degradation in the study area: conditions and patterns

Given these geographical characteristics, they have had a clear influence on the dominant vegetation type in the region, therefore *Stipa tenacissima* are among the most widespread plants in the Algerian high plateaus, estimated at 18% of the pasture area. The allies have abundance and peak environmental value because they fill the dry sandy plateaus and their slopes, and they also occupy a significant area of hill slopes whose height ranges between 400-1400 meters, and they are among the most important plants Resistant to cold winters and high summer temperatures and has a great ability to withstand drought. However, what is noticeable in this regard is the decline of large areas of *Stipa tenacissima* in 1968, the degraded area reached 1.5% (Suwaisi, 2022). these vegetation characteristics reflect the

interaction between the prevailing continental semi-arid climate of this geographical environment on the one hand, and its location as a transitional zone between the northern mountainous region and the Saharan Atlas to the south on the other hand, which places it in a rain shadow zone. This climatic setting has contributed to the predominance and distribution of the following plant species: *Stipa tenacissima*, *Atriplex halimus*, *Lygeum spartum*, *Athrophytum scoparium*, and little of *Pinus halepensis*. In addition, the woodlands include some stands of *Pinus halepensis*, *Juniperus*, and *Pistacia* shrubs, which are mainly concentrated on the northern slopes of the Saharan Atlas mountains.

The central high plateaus generally constitute a fragile ecological zone characterized by sparse steppe vegetation, low biological productivity, and limited natural regeneration capacity. The vegetation is mainly composed of perennial species, shrubs, halophytes, and herbaceous plants, with *Stipa tenacissima* being the dominant species. Despite its high resistance to drought and soil erosion, this species has experienced severe degradation across the region. This decline is primarily attributed to a combination of recurrent extreme drought events, overgrazing pressure, and sand encroachment processes, which collectively accelerate land degradation in this semi-arid environment. The Algerian desert at a rate of 87%. The northern margins of this Sahara (desert) extend along the lands of the high plateaus environment, making it in great danger. Which represents the main element in the environmental balance and regional development in Algerian regions, and desertification is the main problem facing the high plateaus region as this has resulted in a negative impact on vegetation and the high plateaus area in general:

The encroachment of sands into the high plateaus lands has led to the erosion of scrublands covered with *pinus halepensis* trees and the degradation to vast surfaces of high plateaus environment vegetation, especially *Stipa tenacissima* (fig.3), with *Artemisia herba-alba*, *Athrophytum*, *lygeum spartum* and *Scoparium*. Additionally, some drought resistant shrubs such as *Ziziphus lotus* and *Artiplex halimus* are also affected. These species represent most of the plants in the Algerian high plateaus (HDCS, 2010). These scattered plants, especially *Stipa tenacissima*, Field investigation has demonstrated that vast areas of *Stipa tenacissima* have vanished in the Djelfa region for example, estimated at about 60% of the total area of the central High Plateaus. Its surface area declined from 800 thousand hectares in 1976 to only 288 thousand hectares in 2018, meaning that it lost about 70% of its plants over the past 40 years (FGN, 2019).

Consequently, sand encroachment are the leading factors threatening land degradation. It is concluded that vegetation degradation represents the most significant challenge threatening the central steppe region.

4.2. Analysis of land degradation dynamic indicators in the study area

To enhance the accuracy of the study, Sentinel-2 imagery covering the period 2020–2025 was used as a representative case for the study area. This period was selected due to the occurrence of severe and successive drought events in Algeria over the last quarter of the 21st century. These results are illustrated in the following figure .5:

Based on the Sentinel-2 satellite image, which is the original source that we relied on to calculate both the desertification index (*DVI*) and the vegetation cover index (*NDVI*), and after calculating these two indicators according to the following basic equation:

So the equation according to Sentinel-2 of (*NDVI*)=An exception to this is a:

$$NDVI = \frac{B8 - B4}{B8 + B4} \quad \text{This is if we know that the normal basic equation is: } NDVI = \frac{NIR - RED}{NIR + RED}$$

So the equation according to Sentinel-2 of (*NDVI*)=An exception to this is a:

$$DVI = (B8 - B4) / \text{where the basic equation is: } DVI = (NIR - RED)$$

Accordingly:

-Band8 (*B8*) = near infrared wave / 842 nm:

Band8= *NIR*

-Band4 (*B4*) = red / 665 nm wavelength: Band4= *RED*

And through the calculation of the *NDVI* and *DVI* indices were calculated from Sentinel-2 imagery to assess vegetation dynamics and desertification processes. The results revealed a direct relationship between desertification intensity and vegetation degradation, whereby increasing desertification indices corresponded to decreasing vegetation density. **Accordingly, the following can be observed:**

The study area is predominantly characterized by bare soils or gravel-covered surfaces, with *NDVI* values ranging between 0.00 and 0.2, corresponding to severe desertification zones. These areas cover approximately 38,622 km², representing 49.62% of the total central High Plateaus (Fig.5). They are mainly distributed across most of Djelfa Province and the central and western parts of M'sila Province. Areas classified as very severe desertification are represented in dark red, covering about 36,052 km² (46.32%) (Fig.5). These zones

include nearly the entire Laghouat Province, particularly due to its location along the northern fringes of the Sahara.

In contrast, non-vegetated zones appear in light yellow on the *NDVI* map. Sparse and discontinuous vegetation patches, mainly located in central Djelfa and southeastern M'sila, appear in green. These areas account for only 0.17% and 2.94% of the total study area (Fig.5), respectively, and correspond to weak or scattered vegetation affected by low-intensity desertification.

4.3. Analysis of spatial variations in the green dam perimeter

The central high plateaus region accounts for a significant portion of Algeria's non-Saharan territory and serves as the primary source of fodder for livestock production exclusively, the provinces of M'sila, Djelfa and Laghouat is represents the largest steppe region in this vast environment for example. Ranking first in Africa with a total area of approximately 2,381,741 km². Algeria is characterized by its vast desert (Sahara), which covers about 87 % of the national territory.

The lack of rainfall, and weak irrigation techniques led to the dominance of rain-fed agriculture of dry grains in the steppe, with an area of 7,228,840 ha (24%) this has contributed to the degradation of agricultural soil, and the equivalent of 67% of the 20 million-hectare steppe is threatened by desertification (Yahiaoui, 2016). But, overgrazing has led to the deterioration of large areas of its trees, about $\frac{2}{3}$ of its area, of which 63% is pastoral land, equivalent to 2.23 million hectares, and 18%, equivalent to 662741 hectares, threatened by the creeping sand that surrounds them from all sides. Its trees have become threatened with disappearance in the face of the advancing sands that surround them from all sides. However, the Algerian state worked on rehabilitation the project under executive decree No. 30-213 (Gazette, 2020).

Overgrazing in this fragile environment poses a serious threat to ecosystem stability, leading to the rapid depletion of perennial vegetation and accelerated soil erosion, as more than 200 million hectares out of 238 million hectares are under threat of desertification alarming figure indicate to 13.821179 hectares are under desertification threat, equivalent to about 67% of the surface area of the high plateaus (Zanoun, 2010). It was estimated at 12 million heads in 1995, This helped desertification spread towards the GREEN DAM perimeter (Fig.6). It can be seen that overgrazing is considered one of the main causes of the degradation of steppe pastures. In fact, the

increasing number of livestock also play a significant role in this degraded alongside desertification. While the number of livestock in the steppe environment was about 12 million heads in 2000, today it has reached 20 million (Ghazi, 2003). These millions of livestock, especially with the lack of respect for protected pastures reflect the excessive exploitation that has led to the destruction of the vegetation, particularly *Stipa tenacissima* and *Artemisia harba-alba*, as previously mentioned. As a result, the steppe pastures can no longer support at least four times their actual carrying capacity for livestock herds. see (tab.2).

In order to highlight degraded lands within the Algerian Green Dam perimeter, a comparative analysis of the Land Degradation Index (LDI) and the Normalized Difference Vegetation Index (NDVI) was conducted over the same period considered for the Central High Plateaus study area (2020–2025). Although the Green Dam was established in 1971, the focus on the last five years is justified by the occurrence of successive severe drought waves, which represent the most critical period in terms of environmental degradation. These climatic conditions have not only accelerated land degradation across the Central High Plateaus but have also contributed to significant vegetation and soil degradation throughout the Green Dam, particularly within the study area, as illustrated in Fig. 7:

- The area of severely degraded lands within the Green Dam perimeter remains very limited, covering no more than 1.011 km² (1.30%) (Fig.7). These areas appear in dark red and are mainly concentrated in the northernmost and eastern parts of M'Sila Province. In the NDVI map, they correspond to zones with index values ranging between 0.30 and 0.40, represented in dark green.

- A noticeable increase in moderately degraded lands is observed within the Green Dam perimeter. Represented in light red, these areas cover about 8.042 km² (10.33%) and extend across most of M'Sila and Djelfa Provinces (Fig.7), reaching northern and western Laghouat. In contrast, lands showing slight or clear improvement remain limited, covering no more than 4.734 km², with proportions ranging between 1% and 6% (Fig.7). These areas correspond to mean NDVI values between 0.05 and 0.10 (Fig.7), displayed in light green to whitish tones.

- The remaining areas within the Green Dam perimeter are predominantly degraded lands affected by desertification and characterized by sparse vegetation cover. These areas cover approximately 62,895 km² (80.80%) and appear in

yellow to whitish tones (Fig.7). They dominate most parts of the Green Dam perimeter as well as the study area overall. On the mean NDVI map, these zones correspond to very light green to yellowish colors, indicating highly degraded conditions (Fig.7). It can be concluded that the Algerian Green Dam perimeter is undergoing continuous degradation despite the limited extent of severely degraded lands. Although reforestation programs are being implemented by the Algerian authorities through the General Directorate of Forests and the High Commission for Steppe Development, the expansion of moderately degraded areas—affected by vegetation decline, tree deterioration, and sand encroachment due to drought and overgrazing—remains a major environmental concern. This situation calls for urgent measures to revive the Green Dam project and accelerate the implementation of the environmental and ecological balance protection program initiated by Abdelmadjid Tebboune for the 2020–2030 period.

5. Discussion and recommendations

5.1. Mitigating overgrazing and rehabilitating natural Pastures

The organization of pastoral grazing and rehabilitation of marginal lands are crucial due to the sensitivity of the fragile environment, which has been impacted by rapid natural and human degradation. If we are talking about steppe areas, about $\frac{1}{2}$ of the soil surface, which was covered with plants, grasses and some forests, has been subjected to advanced degradation processes over the past twenty years due to the elimination of allies and the uprooting of grasses and shrubs for cereal cultivation and overgrazing without taking into account the limited potential of this environment sensitive to soil degradation and wind, because it is difficult to renew its vegetation in case of continuous demographic pressure and increase in livestock on pastures. This has led to the doubling of pressure on this fragile environment. The wrong practices of humans in managing rangelands, such as overgrazing and intensify grazing, along with the expansion of the main factors that have accelerated the degradation of the fragile pastures. To preserve natural rangelands, pastoralists must switch from plowing to rotational farming in parallel with controlled grazing and refraining from overgrazing in some rangelands. In addition, the use of chemical fertilizers harmful to soil fertility should be avoided. However, the use of chemical fertilizers in the soil biologically destroys it, leads to changes in its organic matter, and weakens its production

capacity. Excessive use of these fertilizing chemicals not only stops the natural development of the soil, but also leads to the deterioration of the soil and its daughters and start the desertification of ecosystems (Darkal, 2021). which require using organic fertilizers derived of livestock manure to compensate for the loss of nitrogen (No_x).

The Algerian country must adopt a comprehensive and sustainable strategy to preserve the western steppe rangelands. Overgrazing by sheep flocks is common, especially as herders cross the boundaries of sheep and grazing machines. The area assigned to each guard often exceeds 2000 hectares, and in Laghouat province, 270 guards oversee 620000 hectares an average of 2300 hectares per guard (NOS, 2015). The Algerian government's pastoral strategy in the forest reserves was successful in restoring large degraded areas, approximately 280000 hectares (Jaafoura, 2019). It provided forage and productive diversity between 30 and 200 units per hectares, after three years of protection (Zanoun, 2010). It also helped regenerate shrubs and bushes, restoring plant species with high nutritional value, improving soil cover by 30% to 40% (HCDS, 2010). This played a role in protecting the soil fertility, increasing water retention capacity, and enhancing biological resistance. Thanks to this, the Algerian state was able to improve soil organic matter, high, total nitrogen (No_x), and protect pastoral lands.

5.2. Reactivation of the green dam project and vegetation protection strategies

The area of afforestation and rehabilitation of vegetation, whether within the dam area or the surrounding areas, in Djelfa Province reached 7,218.37 km^2 for example, especially since this state is the axis of the GREEN DAM and the largest pastoral state in terms of grazing in the central Algerian steppes. There is an increase in the area of afforestation and rehabilitation of pastures and agricultural lands alone, which alone amounted to 5,669.2 km^2 , not counting the area of rehabilitation of the GREEN DAM, which is about 584 km^2 (Fig.8). The area of afforestation and vegetation intensification has been increasing in recent years from 2020 to 2025, it is clear that Algeria is currently working on implementing many afforestation programs to rehabilitate the GREEN DAM through afforestation and intensifying afforestation by planting many types of shrubs and pastoral plants. This process is part of the national strategy that aims to combat desertification, preserve pastoral reserves, and stop sand encroachment, whether in Djelfa

Province or other regions Laghouat and M'sila there are stills threatened by severe desertification and need regional preparation to achieve environmental balance and sustainable development. In order to protect the remaining vegetation and forests in the central high plateaus, current Algerian President Abdelmadjid Tebboune has attached utmost importance to the rehabilitation of the GREEN DAM within the framework of the Sustainable Steppe Development Program (2020-2025), according to the following strategy:

- Establishment of the independent authority for combating desertification and rehabilitation the GREEN DAM under executive decree No.30-213 dated 30/7/2020. Its mission focuses on reforesting this GREEN DAM and desertification control (Gazette, 2020).
- The state allocated projects for the development of the GREEN DAM within the framework of the 2020-2023 climate plan, with Algerian president Tabboune supporting this plan as a national development involving all active sectors (75 billion DZD) Equivalent to a value of \$562 million, with the project's funding renewed annually in accordance with the Algerian Finance Law for a period of 7 years Starting in 2023 (Sakhri, 2024).
- Rehabilitating the GREEN DAM and expanding its area starting October 29, 2023, as a first step towards sustainable development and combating desertification and climate change by expanding

the afforestation area from 3.7 million hectares to 4.7 million hectares in steppe areas (Orabi, 2025).

- Embodying the Algerian state's efforts since 2025 and implementing sustainable steppe development programs can only be achieved through the establishment of a coordinating body to combat desertification and rehabilitate the *GREEN DAM*. Among the most important tasks of this body, which consists of several different ministerial sectors, is the planting of more than 6 million trees and plants, and the call for the use of techniques to stabilize sand dunes moving through windbreaks (Salamani, 2023).

Therefore, the following recommendations are proposed to protection of steppe pastures across the central high plateaus of Algeria

- Enforce deterrent legal mechanisms to prevent grazing in protected green zones and curb unauthorized plowing.
- Promote reforestation and seed diversification to restore high-nutrition vegetation, thereby increasing fodder availability and livestock efficiency.
- Monitor overgrazing through integrated cooperation between key stakeholders (HCDS, Forestry and Agricultural Directorates, and the National Federation of Livestock Breeders).

From the foregoing, it can be concluded that Algeria's environmental policy has contributed significantly to the rehabilitation of the natural environment and the restoration of ecological balance through shrub plantation programs within the Green Dam belt and the development of protected areas in the study area.

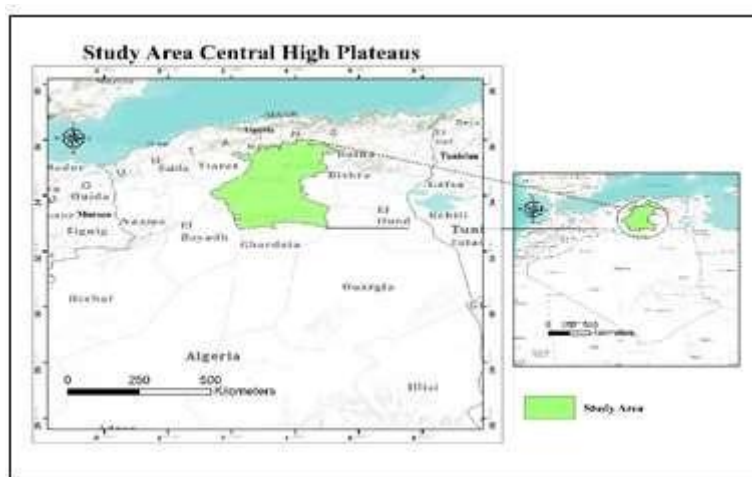


Figure 1. Geographical Location and Boundaries of the study area (source: the administrative border map of the National Agency for Territorial Amenagment using ArcGis 10.8)

Table 1. Ecological Characterization and Spatial Distribution of Study Area

Provinces	Surface (ha)	Ecological type
M'sila	1.870000	Semi-arid pastoralism

Djelfa	2.924460	Semi-arid pastoralism
Laghouat	250.0000	Arid pastoralism
Total Study area (4.794410 ha)		
Total high plateaus 20.724.048 ha		

Source: The High Commission for steppe development, Algeria, 2020.



Figure 2. The Green Dam stretches across the High Plateaus, from the western border to the Tunisian border in the east, over a distance of 1,500 km. (Source: <https://mosta.cc/fh58i> Using google earth)

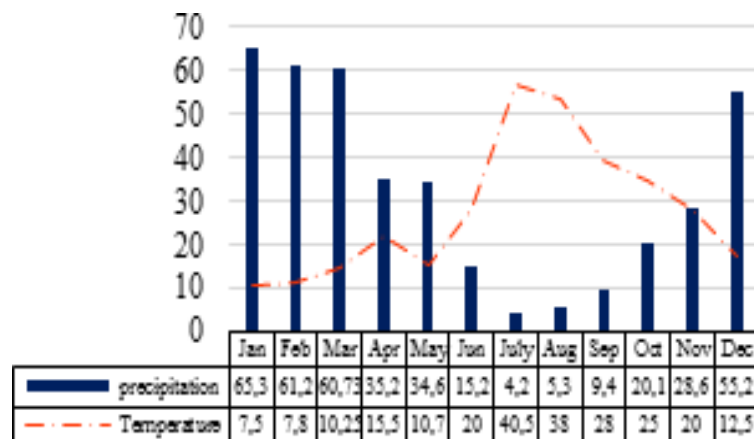


Figure 3.Quantities rainfall and temperatures in the study area during the period 2005 - 2020 (Source: the meteo-stations to Djelfa and Laghouat, 2021)



Figure 4. Sand Encroachment and Land Degradation of *Stipa tenacissima* and *pinus halpensis* in the Algerian Green Dam: The Provinces of Laghouat and M'sila as a model in study area (Source: HDCS ,2018)

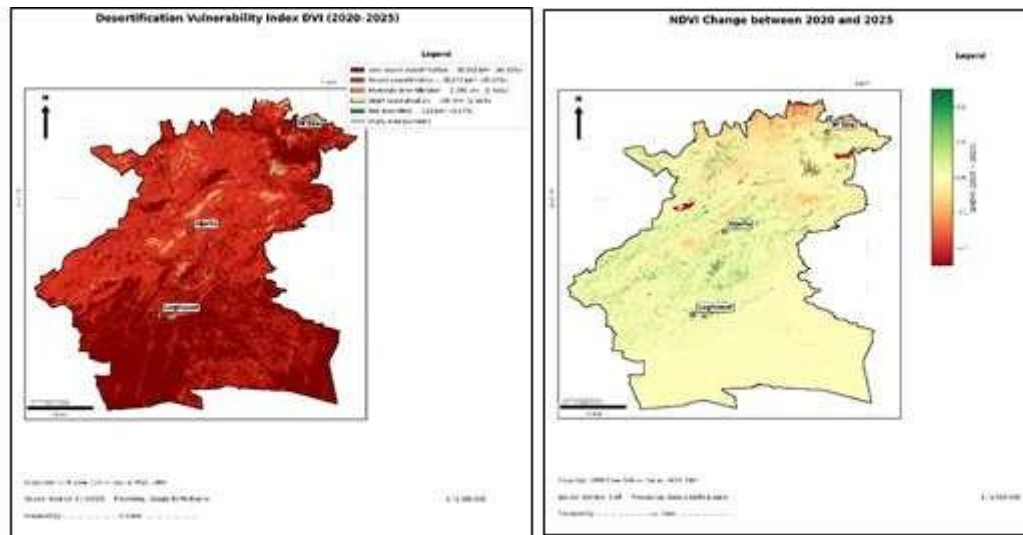


Figure 5. Desertification vulnerability index (DVI) and Change Normalized Difference Vegetation Index (NDVI) in the study area between 2020-2025 period (Source: Projection UTM 31N-Datum: WGS 1984- Database of ESRI - Sentinel- 2 SR- processing Google earth engine, 2026)



Figure 6. Overgrazing attack on an *Stipa tenacissima* protected steppe pasture adjacent to the Green Dam perimeter in Laghouat and Djelfa province (Source: Hadjadj Nejat, rural transformations and agricultural land reclamation in the steppe regions bordering Oued Touil a case study of Tiaret and Djelfa provinces, PhD Thesis in Geography and Regional Planning, University of Oran 2, 2023, p. 205)

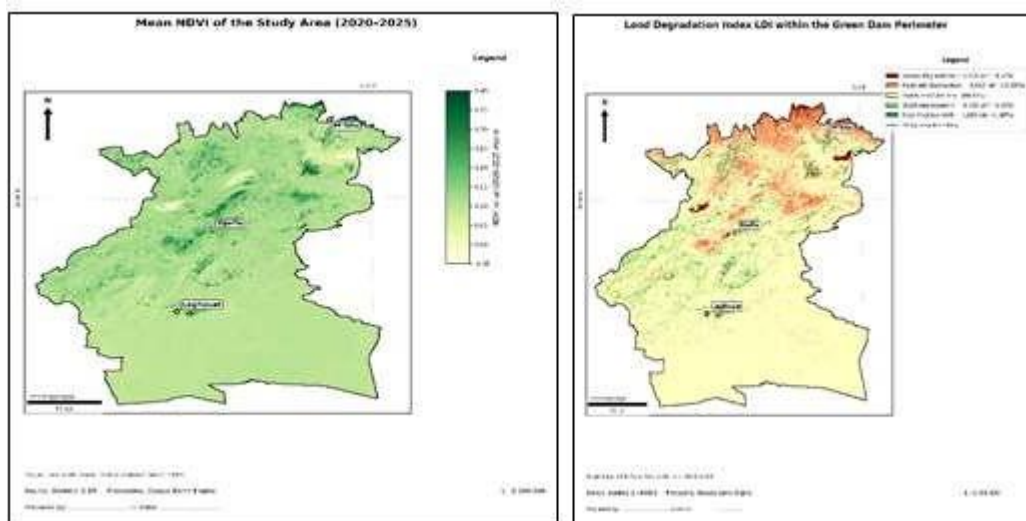


Figure 7. Comparative between the Normalized Difference Vegetation index and Land Degradation in the Green Dam perimeter (2020–2025) (Source: Projection UTM 31N-Datum: WGS 1984- Database of ESRI - Sentinel- 2 SR- processing Google earth engine, 2026)

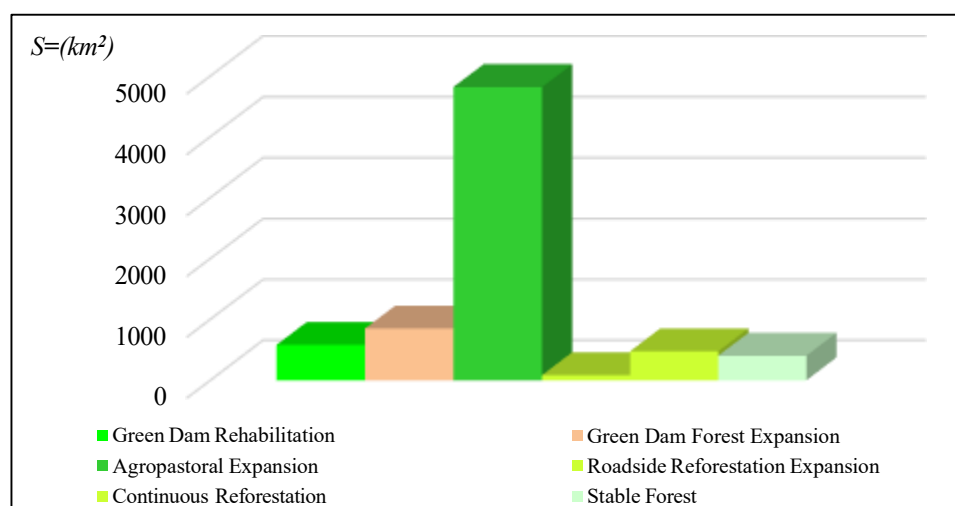


Figure 8. Agro-pastoral restoration and forest expansion in Djelfa province as a model for the 2020–2025 period. (Source: Orabi.S. M et al. (2025), *The Green Dam in Algeria: from an Ambitious project in 1971 to an environmental rehabilitation strategy in 2023*, *Journal of information systems engineering and management*, 10(4), 1822-1824.

Table 2. Condition of Natural Pastures in the High Plateaus between 2005-2025 period

level of degradation	Productivity (Feed units/hectare)	Surface (hectare)	Percentage of total area
Good	120	3000000	23.07
degraded	70	5000005	38.46
Severely degraded	30	5000006	38.47
Total area	220	13000011	100

Source: Report of the High Commissioner for Steppe Development (HDCS), Algeria, 2020.

6. Conclusions

This study demonstrates that the central high plateaus of Algeria and the Green Dam belt are undergoing significant land degradation and increasing desertification pressures driven by climatic variability and unsustainable human activities, particularly overgrazing and vegetation depletion. The spatial analysis based on Sentinel-2 imagery revealed a continuous decline in vegetation and an expansion of degraded lands, especially in highly vulnerable plateau environments.

The results confirm the effectiveness of remote sensing and GIS techniques in monitoring land degradation dynamics and identifying areas most exposed to ecological deterioration. In this context, strengthening sustainable grazing management, restoring degraded steppe ecosystems, and rehabilitating the Green Dam using climate-resilient species constitute essential measures for reducing desertification risks and improving environmental resilience.

Ultimately, the preservation of ecological balance in the central high plateaus of Algeria represents a strategic priority for achieving sustainable

environmental and socio-economic development in semi-arid regions.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
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