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Spatio-Temporal Evolution of Livestock Dynamics and Vegetation Cover Transformation in the Algerian Steppe, Diachronic Analysis

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Abstract
This study aims to highlight the importance of livestock dynamics and the evolution of the vegetation index in recent years, as well as to present the relationship between these two dynamics in the Algerian steppe in light of a new vision in the use of geographic information systems in the treatment of environmental and agricultural development in animal production. The Algerian steppe, with its unique characteristics of the bio-climatological factors, natural resources as a specific vegetal cover and animal species wealth, economic activities, cultural backgrounds, and practices, has deteriorated in recent years from total and/or partial denaturation of vegetation and pastoral spaces. This denaturation was caused in the first place by biological factors associated with economic breeding activities and affected the sustainable development of the steppe area. To propose an efficient strategy to provide the natural ecosystem of the steppe area, vegetation cover balance, and the maintenance of food security by livestock and the sustainable development of the communities, many study scenes were created by using spatiotemporal monitoring of the evolution of natural resources using LANDSAT satellite images and the Q GIS dataset. Using remote sensing and geographic information system (SIG) data, his changes during 2017-2021 may be detected using knowledge of vegetation and livestock distribution dynamics. The areas with the highest concentration of livestock herd possess a low vegetation index, indicating a significant correlation between the intensity of the vegetal cover denaturation and the growing dynamics of livestock herd.

Keywords: dynamic; livestock; spatio-temporal; steppe; vegetation index.

Introduction

The Algerian steppe represents a significant ecological zone, characterized by a distinctive ecosystem that underpins extensive pastoral activities and functions as a crucial area for livestock production (Hadbaoui, 2021). The breeding system is one of the most important aspects of socio-economic development in semi-arid lands due to its high productivity, particularly for sheep (Senoussi and al., 2019), goats, and camels, which are key resources in these regions (Siad and al., 2022). Nevertheless, animal breeding can have a double-edged effect, positive and negative, on sustainable development in the steppe regions. Overgrazing poses increasingly significant problems for this delicate ecosystem, resulting in desertification and vegetation destruction (Hadbaoui, 2021).

For these reasons, the concept of sustainable green development has become a fundamental strategy for improving the health of steppe ecosystems, focusing on its two primary components: crops and breeding systems (Zikri and al., 2021; Ali and al., 2021).

Currently, the integration of advanced technologies such as remote sensing and Geographic Information Systems (GIS) is essential in achieving sustainable green development. Remote sensing provides critical data for monitoring large areas over time, allowing for the detection of changes in vegetation cover, land use, and bioclimatic conditions. When combined with GIS, these tools offer a comprehensive approach to analyzing spatial and temporal patterns, enabling decision-makers to evaluate environmental impacts and guide sustainable land management practices Zhang and Cao, 2019).

Numerous studies worldwide have addressed the importance of GIS and remote sensing in achieving sustainable development in semi-arid regions, in addition to examining the particularities of the Algerian steppe and the role of GIS in studying the relationship between livestock production and vegetation. However, these studies have not adequately investigated this importance in the context of the Algerian steppe, especially in recent years (Blanco and al., 2018; Sahnouni and Abdesselam, 2018; Castro and al., 2019; Boukerker and al., 2021: Hadjadj and Hadeid, 2022 and Senoussi, 2024).

This study aims to demonstrate the nature of vegetation and livestock dynamics between 2017 and 2021, with a theoretical examination of the relationship between these two entities. In addition, the study focusses on the importance of GIS technology in enhancing sustainability in the Algerian steppe and proposes strategies to preserve balance in this delicate ecosystem.

Materials and Methods

1.Presentation of the study area

The Algerian steppe covers an area of 20 million hectares, which extends to 30 million hectares when including the pre-Saharan steppes (Blanco and al., 2008; Bastin and al., 2012). It comprises 14% of Algeria's total area and is geographically defined as a band stretching 1000 km from east to west, with a width varying from 300 km to less than 150 km in the east (Figure 1) (Bencherif, 2011), The steppe is bounded by the 100 mm isohyet in the south, marking the southern limit of Alfa grass (*Stipa tenacissima*) expansion, and the 400 mm isohyet in the north, corresponding to the extension of dry cereal crops (Chaouch, 2019).

For Senoussi and al., (2019), the steppe is a transitional area between the Sahara Desert and the northern littoral region, characterized by broad, level, and high areas with sparse tree cover.

According to Nedjraoui and Bedrani (2008)**,** subsets of the steppe were distinguished as follows:

-The sub-steppe edge, which measures 400-300 m.

-The appropriate isohyet range for the steppe is 300-200 m.

-The isohyets 200-100 m zone of the Pre-Saharan steppe.

Using modern geographic location methods from Google Earth, the steppe region is situated between 0° 18′ 52″ west and 8° 06′ 59″ east longitude, and between 35° 52′ 39″ and 33° 40′ 49″ north latitude.

This region, encompassing 11 wilayas and 430 municipalities (Figure 1), continues to hold strategic importance for the nation (Amil, 2023).

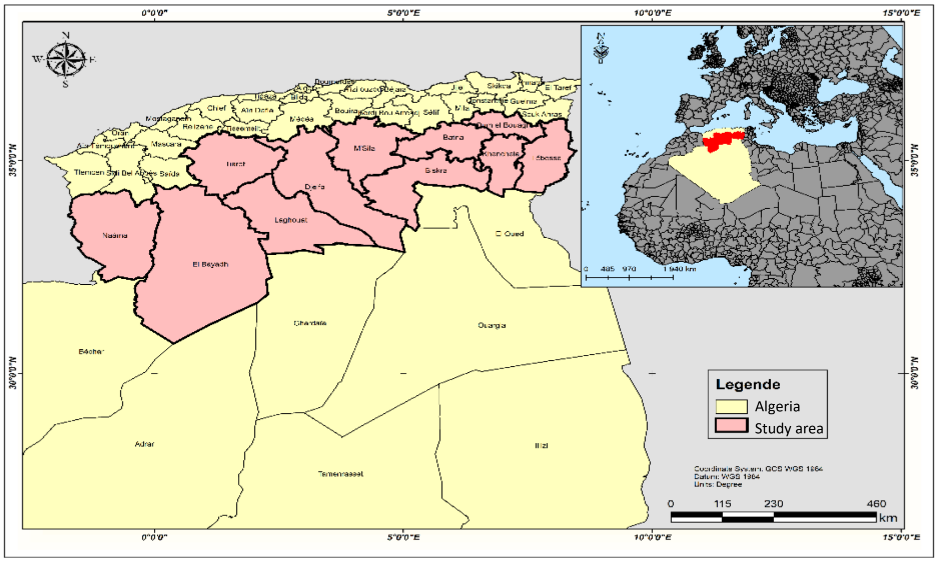

Figure 1. Presentation of the study area localization

The study area is characterized by:

- Three bioclimatic stages: lower semi-arid, upper arid and lower arid (El Zerev and al., 2009).

- Excessive heat with insufficient and variable precipitation; however, Bouchoukh (2010) reported that there are climate contrasts.

- A rainfall coefficient between 24.5 and 27.7, and an average annual precipitation of 271 mm;

- An average minimum temperature of -0.5°C in the coldest month, and an average maximum temperature of 34.5°C in the warmest month.

- The dry season often lasts from April to October, more than 7 months (Benabdeli, 2000).

Steppe soils are characterized by low organic matter content, high vulnerability to deterioration, and the presence of calcareous deposits that reduce the depth of usable soil (Khaldi, 2014). The majority of the steppe zone is located between the Tellian Atlas and the Saharan (or pre-Saharan) Atlas (Figure 2). This area forms high plateaus ranging from

900 to 1200 meters in elevation, constituting the Maghrebian steppe domain, which is broadly referred to as the High Plains (Khenioui and al., 2023).

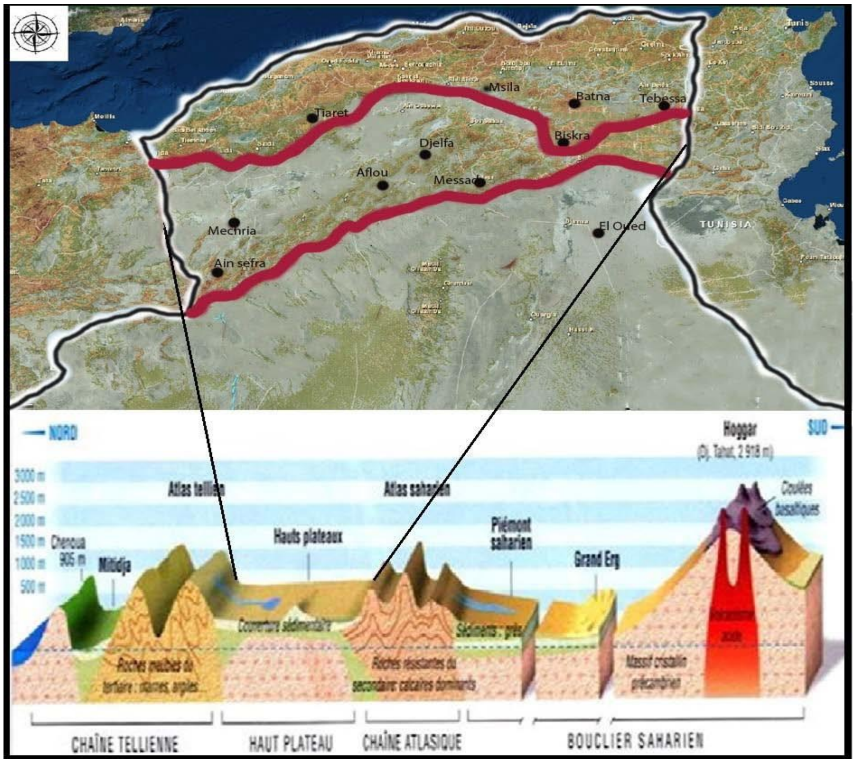

Figure 2 .The topographic characteristics of the research region (Gaci, 2022)

2.Land occupation

The 20 million hectares of the steppe zone are composed of 11 million of barren soil and 5 million of cultivated land, maquis, tree steppe, and unproductive land (sandy or saline areas) that constitute 2.5 million hectares. In addition, 1.4 million hectares of forests and scrub (Figure 3).

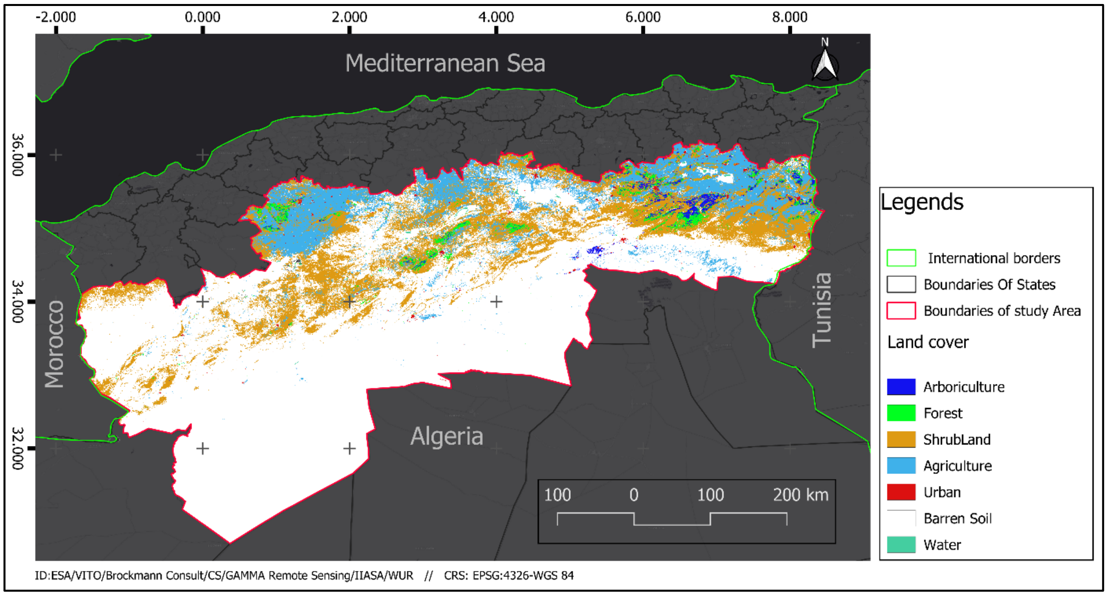

Figure 3. Land occupation in the study area in 2021

3.Methodology

This study highlights livestock's dynamics, and vegetation index evolution in the Algerian steppe area from 2017 to 2021. The methodology, based on El Zerev and al. (2009) with modifications, consists of two parts: data collection and analysis.

a/Data collection

The study utilized two types of data:

- Cartographic data: LANDSAT satellite images from Google Earth Engine (2017, 2021) for vegetation cover evolution and vegetation index analysis. LANDSAT was chosen for its: i) Wide coverage: 16-day orbital cycle providing comprehensive land use and cover change perspective. ii) High spatial resolution: ≤30 meters, enabling detailed examination of small features. iii) Multiple spectral bands: Allowing investigation of various data types (e.g., moisture content, surface temperature, vegetation health).

- Socio-economic data: Livestock herd evolution data (2017-2021) from the Ministry of Agriculture and Rural Development.

Additionally, a socioeconomic survey was conducted with officials from the Ministry of Agriculture and Rural Development authority (MADR) to aid result interpretation.

b/Methodology for processing satellite images

The process involved:

1. Delineating the study area and excluding irrelevant image portions.
2. Geometric correction using the GCS WGS 1984 projection method.
3. Image processing using Red, Green, and Blue (RGB) color channels.

c/ NDVI Calculation

The Normalized Difference Vegetation Index (NDVI) was computed using the red and near-infrared (NIR) bands from Landsat images. NDVI is calculated as follows:

$$NDVI=(NIR+Red)/\ (NIR-Red)$$

The changes in the vegetation cover throughout the chosen years (2017–2021) were evaluated using this index. In contrast to earlier approaches outlined in El Zerev and al. (2009), which concentrated on mapping land-use/land-cover through visual inspection, this work explicitly uses Landsat images to generate NDVI for assessing the density and health of vegetation across time.

d/Interpreting and Categorizing Images

Following the NDVI computation, a classification procedure was used on the pictures. By manually defining vegetation units and sub-classes using pre-established keys, interpretation was carried out.

The livestock dynamic over the years of study is geospatial referenced according to the MADR data for each state and per year.

Representative maps were taken out through a program QGIS 3.28.3 'Firenze'.

e/Data integration and analysis

Graphs were used to visualize the relationship between livestock dynamics and vegetation changes; once the NDVI maps were created, a conceptual analysis was performed using livestock density data collected over the same period. This spatiotemporal and graphical analysis enabled the identification of patterns and trends in vegetation degradation associated with changes in livestock numbers.

Results and discussion

1.The dynamic of the livestock herd in the steppe area between 2017- 2021

Livestock plays an essential role in human life, providing a crucial source of protein through products and by-products such as meat, milk, cheese, and other dairy items. In developing countries, livestock significantly contributes to rural livelihoods and economies, generating income and employment for stockbreeders and associated workers (Herrero and al., 2013).

Global demand for animal products (meat, milk, and dairy) is expected to increase due to population growth, changing dietary habits, accelerated urbanization, and improved household purchasing power. The livestock sector represents a vital source of employment and income for both populations and national economies (Laouali, 2014).

In recent years, to achieve sustainable local food security, Algerian authorities have adopted a strategic approach to valorize and increase livestock productivity and resilience across all regions of the country (Sadoud and al., 2019), with particular emphasis on the steppe region. This area is the most significant livestock production zone nationally, especially for sheep and goats. These initiatives have positively impacted livestock numbers in the Algerian steppe region.

Figure 7 (a, b, c, d, and e) illustrates the development of livestock populations (sheep, goats, cattle, and camels) in this area between 2017 and 2021.

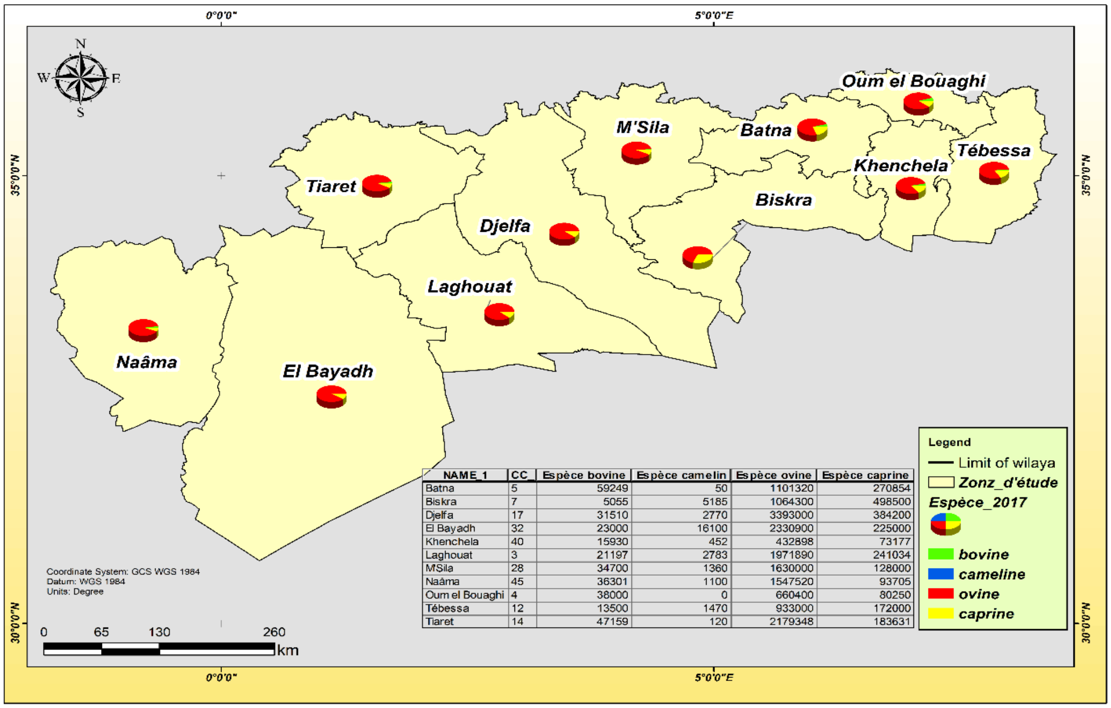

Figure 7. Livestock herd dynamic in the steppe area by wilaya between 2017- 2021 (a: 2017- 2018)

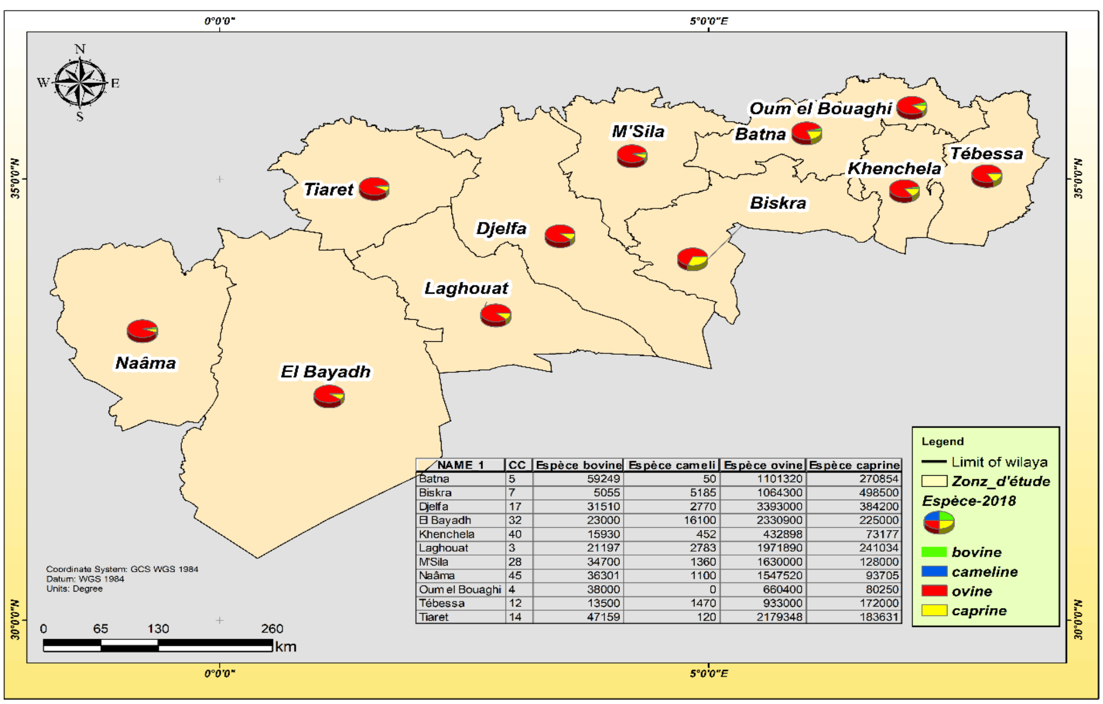

Figure 7. Livestock herd dynamic in the steppe area by wilaya between 2017- 2020 (b: 2018- 2019)

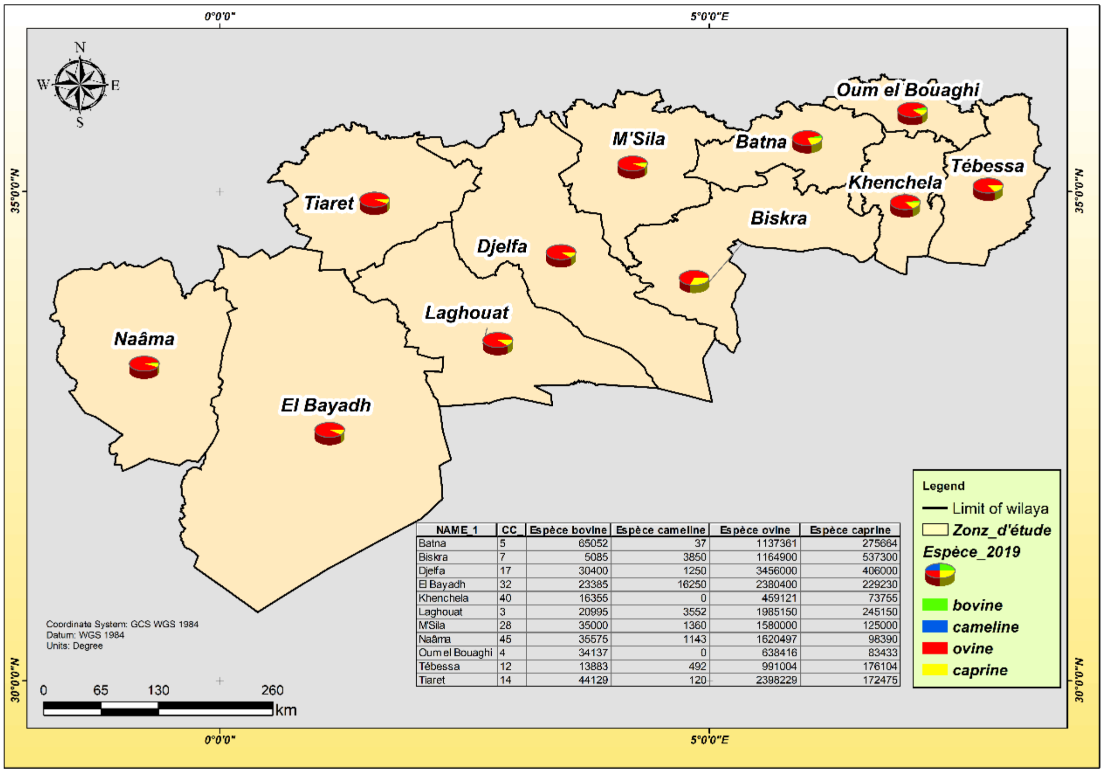

Figure 7. Livestock herd dynamic in the steppe area by wilaya between 2017- 2021 (c: 2019- 2020)

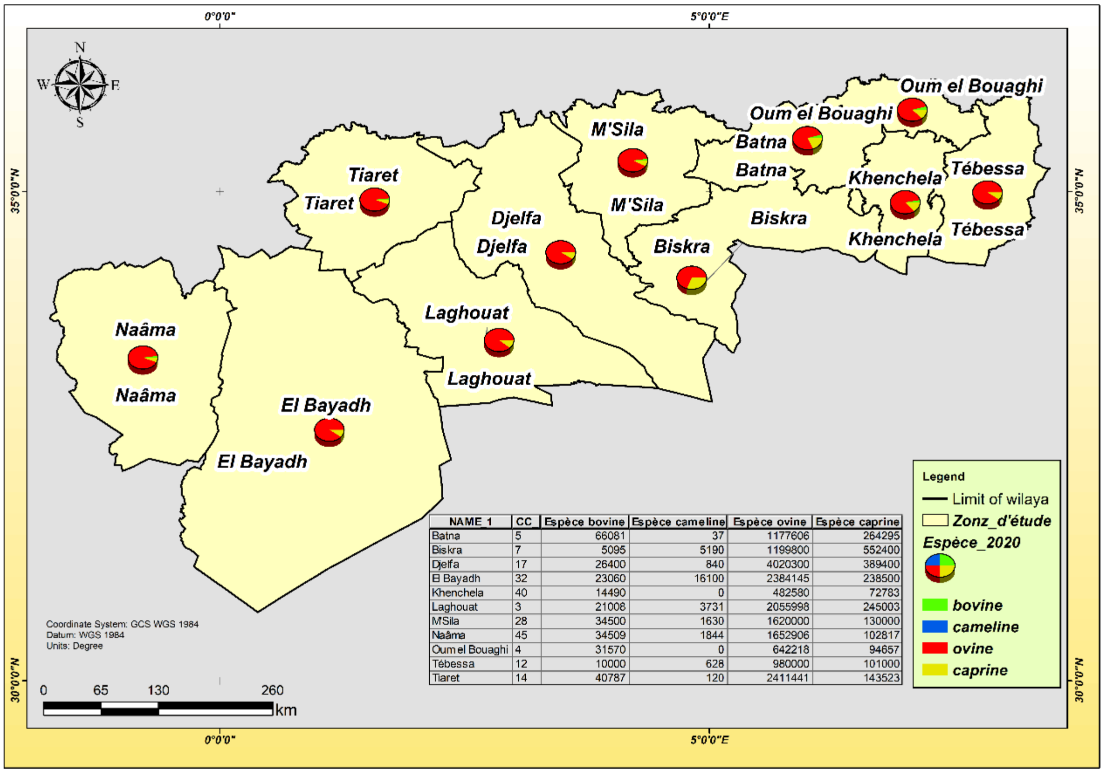

Figure 7. Livestock herd dynamic in the steppe area by wilaya between 2017- 2021 (d: 2020- 2021)

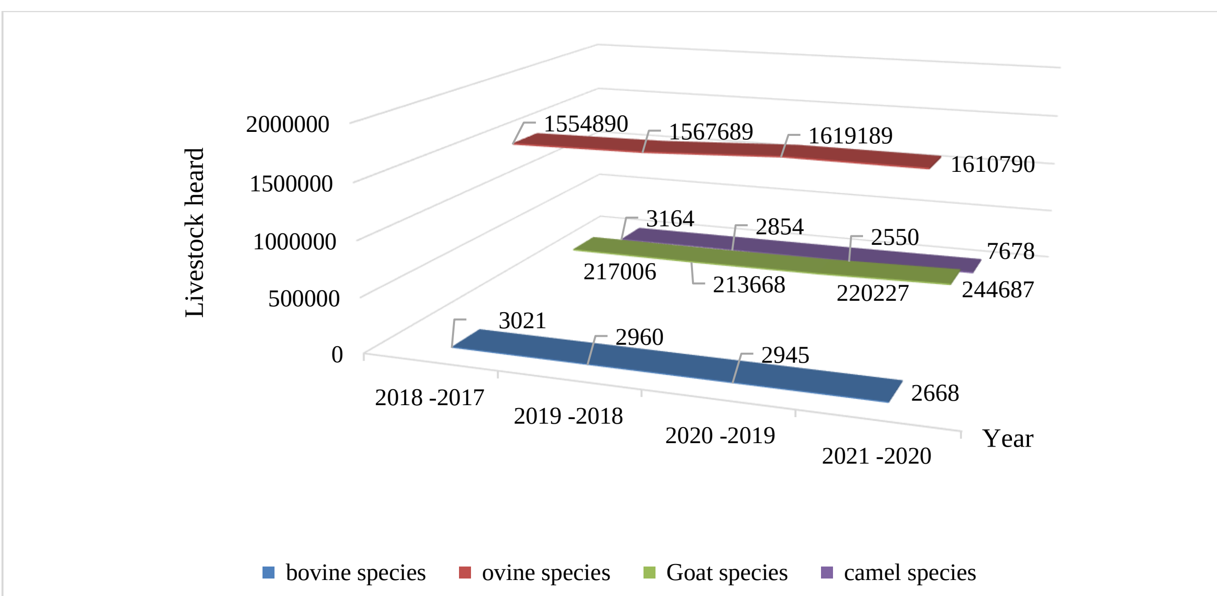

Figure 7. Livestock herd dynamic in the steppe area between 2017- 2021 (e: The total evolution)

Between 2017 and 2021, the steppe area experienced an increase in livestock numbers, particularly for ovine, goat, and camel species. However, bovine species showed a significant decline, from 30,203 head in 2018 to 26,688 head in 2021 (Figure 7: e). This decrease may be attributed to the region's low interest in bovine breeding compared to other species, as well as the climatic requirements of cattle, which are not well-suited to semi-arid regions. In the steppe area, socio-cultural habits significantly influence livestock rates, with 68% of inhabitants practicing sheep farming as their primary economic activity. This results in a substantial increase in sheep numbers compared to other livestock. The national sheep flock is the primary supplier of red meat, with production increasing annually from 4,195,529 tons in 2017 to over 5,000,000 tons in 2021 (a 6.4% annual increase). It makes a significant contribution to the national economy, with a capital of over 2 billion DZD (Algerian dinar).

In 2021, out of a national workforce of more than 30,905,560 sheep, approximately 20,000,000 were in the steppe region. Sheep numbers increased from an average of 1,554,890 head in 2017 to 1,610,790 head in 2021.

Goats constitute the second-largest livestock population after sheep, with an average of 244,687 head registered in 2021 (showing the highest growth rate at 8% annually). Camels and cattle represent 1% and 3% of the total livestock in the steppe area, respectively, with averages of 7,678 and 2,668 head in 2021.

Market requirements and management practices also influence livestock rates in the Algerian steppe. The local population's eating habits create a higher demand for sheep meat compared to other types of red meat, impacting the profitability and numbers of these animals.

Management practices vary among species. Camels, often used for transportation and increasingly for milk production, are less likely to be kept in large herds for meat production (Faye and al., 2022). Beef cattle may require more intensive management practices compared to sheep, which can affect the number of animals that can be raised.

Sheep farming predominates in the Algerian steppe due to its suitability for the environment and ease of management compared to camels or beef cattle.

In 2020, the highest concentrations of sheep were observed in Djelfa (4,020,300), Tiaret (2,411,441), El Bayadh (2,384,145), and Laghouat (2,055,998). These regions also showed increases in livestock numbers between the study years: Djelfa by 8%, El Bayadh by 4%, and Laghouat and Tiaret by 2%.

Regional variations in livestock dynamics are attributed to differences in management strategies and the animals' adaptation to the semi-arid climate of the steppe regions. The socio-economic status of communities in these areas also affects the demand for livestock products and investment in the sector, influencing overall productivity and dynamics (Imelhayene and al., 2022).

The socio-economic status of the communities in the steppe regions may affect the demand for livestock products and the level of investment in the livestock sector, which can influence the overall productivity and dynamics of the sector in some areas compared to other.

2.The dynamic of the vegetation index in the steppe area between 2017- 2021

The study period was divided into five timeframes from 2017 to 2021 to observe the detailed development and the difference in the dynamic of the vegetation index (NDVI) in the Algerian steppe (Figure 8, 9).

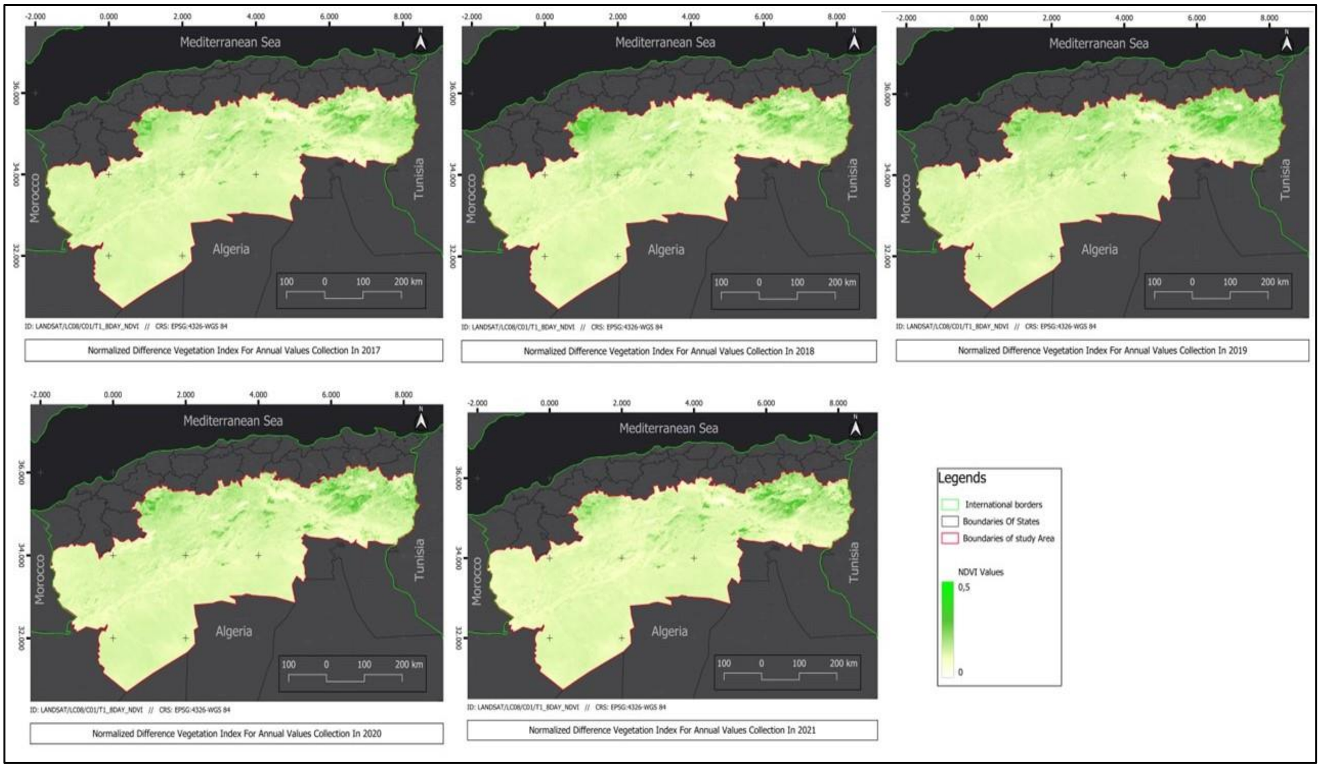

Figure 8. NDVI multi-annual evolution (2017- 2021)

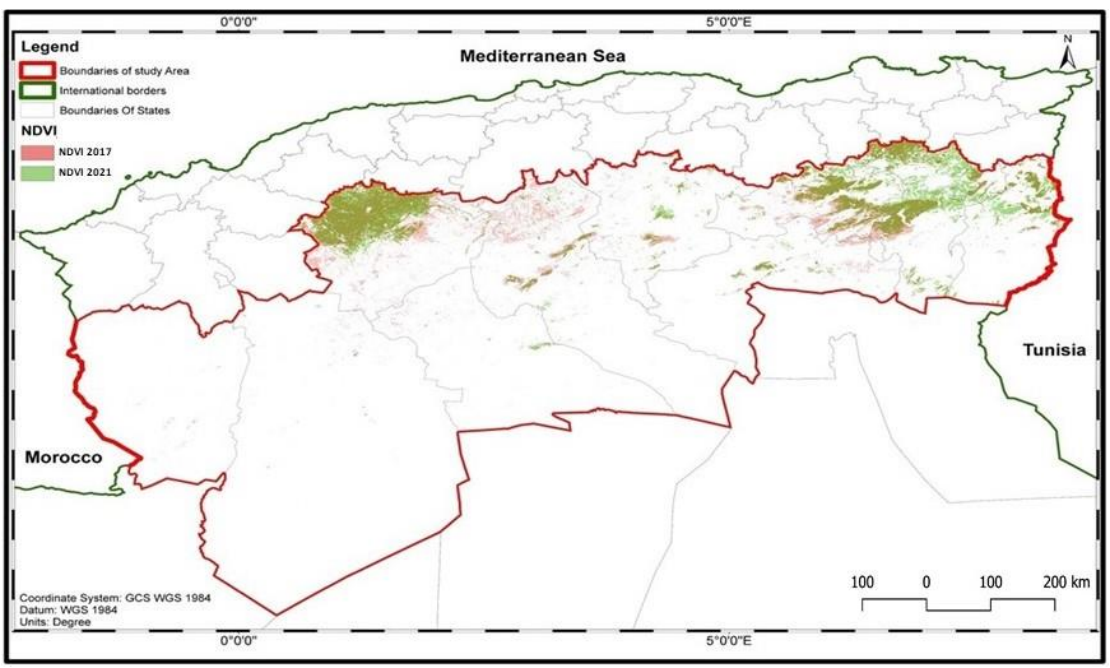

Figure 9. Difference of NDVI data dynamic in the Algerian steppe between 2017- 2021

The Algerian steppe is characterized by a unique vegetation cover adapted to harsh environmental conditions. Shrubs and grasses dominate, with scattered trees in some areas. Common plant species include *Artemisia herba alba*, *Stipa tenacissima* (Nedjimi and Guit, 2012), *Retama raetam* (Nedjraoui and Bedrani, 2008) and *rthrophytum scoparium* (Nedjraoui, 2001).

The vegetal cover is adapted to arid and semi-arid conditions, with many species being drought-tolerant and able to survive in low-nutrient soils. However, this vegetation is threatened by overgrazing, desertification, and climate change, leading to soil erosion, biodiversity loss, and ecosystem service decline (Nedjimi and Guit, 2012). Conservation and restoration efforts are crucial for maintaining the ecological and socio-economic functions of this unique ecosystem.

The steppe area is characterized by limited primitive vegetal cover, expressed by a low vegetation index. Satellite images show the vegetation index is generally weak, with a maximum of 0.5 in Batna, Khenchela, Tebessa, and Tiaret.

Between 2017 and 2020, no discernible change in the vegetation index was observed. However, in 2021, a considerable reduction was noted in the northern steppe states, likely due to partial or complete destruction of pastoral lands from desertification and indiscriminate grazing.

Some areas, especially in Batna, Oum El Bouaghi, M'sila, Biskra, Djelfa, and El Bayadh, present large surfaces of arid land stripped of vegetation.

Although it has many drawbacks, the Normalized Difference Vegetation Index (NDVI) is a useful tool for tracking green vegetation. NDVI is not appropriate for evaluating pasture quality since it evaluates green plant cover rather than standing biomass or the presence of palatable species. In heavily vegetated regions, it tends to be saturated, and non-vegetation factors like ground reflectivity and climate change can impact it and skew the readings. Furthermore, the accuracy of NDVI in diverse environments may be limited by its inability to catch small-scale plant changes due to its spatial resolution. For thorough environmental evaluations, additional indices or field data should be included to the NDVI (Huang and al., 2020; Li and al., 2023).

satellite imagery like Landsat offers a variety of spectral bands that enable different forms of analysis, especially in ecological and agricultural monitoring. The near-infrared (NIR) band is particularly useful because healthy vegetation reflects NIR light strongly, distinguishing it from non-vegetated or degraded areas.

By mapping these bands to different color channels (e.g., NIR to red, red to green, and green to blue), we can create false-color composite images that make vegetation and land changes stand out. Healthy vegetation often shows up as bright red in this false-color imagery, while stressed or sparse vegetation may appear darker red or brown. This technique makes it easier to identify areas undergoing degradation or shifts in land use, which is critical in environmental management and monitoring projects.

*3.**Diagnostic of the vegetation cover situation: livestock- vegetal cover relationship***

With increasing livestock numbers and pastoral movement in recent years (especially in 2021), vegetation damage has intensified, and areas without vegetation have expanded.

States with the highest livestock numbers and rapid development rates show larger areas of damaged lands. Land use practices significantly impact vegetation cover in steppe areas. According to Hadbaoui and al. (2020), Overgrazing can lead to soil degradation, reduced vegetation cover, and increased soil erosion, while sustainable grazing practices can maintain or improve vegetation cover and soil health. Similarly, agricultural practices on rangelands can lead to reduced naturel vegetation cover and soil degradation.

The increase in animal head growth rates necessitates higher animal loads in rangelands, resulting in gradual degradation, particularly in grazing areas for species with little or no selective food behavior, such as caprine and ovine species (Mohammed and al., 2020).

Livestock in the steppe has a dual impact. Positively, it contributes to the economic life of local communities and often holds great cultural and spiritual importance for pastoral communities. Negatively, as shown by satellite imagery analysis, it affects vegetation cover through degradation and consequent biodiversity loss. Conflicts can arise over access to resources, such as water and grazing land, leading to competition and tensions between pastoral communities and other land users.

Pastoral feed represents the traditional resource for animals in steppe regions. However, the decline in forage production in rangelands, caused mainly by overgrazing, obliges breeders to supplement with feed, most often concentrated feed. Despite this supplementation, a large forage deficit remains in the steppe areas. Yousfi and al. (2017) estimated this deficit at 40.5% for the entire steppe.

This analysis is largely theoretical, drawing upon previous studies, field observations (Image 1), and the general observations correlated by livestock population evolution with satellite imagery. A more comprehensive analytical study, incorporating robust statistical analysis, is necessary to fully examine the relationship between vegetation changes and livestock population dynamics. It is important to recognize that the impact of livestock on vegetation is influenced by various factors, including climatic conditions and land quality. Furthermore, the environmental effects of livestock may take longer to become apparent on a broader scale or may be confined to specific localized areas.

Image 1. Comparison between the grazing areas

A. grazing area (Picture taken in: ALGERIA, Biskra., 2017)

B. grazing area (ALGERIA, Biskra., 2021)

Conclusions

Our study shows that Geographic information systems and satellite pictures are important technics for the diagnosting the dynamics of natural phenomena such as vegetation index and livestock dynamic in different areas of the world. This can give us a good view of this development and variation to analyze the influencing factors of this dynamic, and practice new strategies, and decisions for the achievement of sustainability.

Livestock is an important vital resource for the daily activities of the inhabitants of the steppe areas resulting from social, intellectual, and historical backgrounds. It also has the potential to harm the ecosystems of these locations by destroying vegetation, which would be a double-edged sword. As a result, it is a negative manifestation in the context of achieving sustainable development, especially since the ecological dimension is one of the most important to achieve it in these regions.

According to this analytical study, the actual impact of climatic factors on vegetation levels is not so much apparent as that of livestock and their high levels in the demolition of pastoral areas due to overgrazing, especially in areas with high rates of sheep, which is manifested by a permanent animal surcharge on rangelands. It is imperative to develop efficacious methodologies aimed at augmenting the proportion of livestock, with the objective of achieving internal food security for the nation and local steppe regions, while simultaneously safeguarding vegetation areas in the pastures. This endeavor is essential for ensuring biodiversity, environmental security, and attaining natural stability, thereby fostering a positive correlation with the renaissance and civilization indicators of nations.

The negative consequences of livestock farming in pastoral areas can be avoided in several ways:

- Sustainable grazing management: forage crop planting, stocking densities, resting intervals, and rotational grazing systems can all serve to lessen overgrazing and improve vegetative cover.

- Water management: building ponds and water troughs, for instance, can improve water availability for both cattle and wildlife while also reducing competition for this resource.

- Disease control: by putting quarantine procedures and vaccination programs, biosecurity measures can help reduce disease transmission between livestock and wildlife.

- To preserve biodiversity, include wildlife habitat in livestock management strategies.

Author Contributions

Conceptualization: Imelhayene Meriem, Saidj Dahia; Methodology: Imelhayene Meriem, Saidj Dahia, Adamou Abdelkader; Formal Analysis: Imelhayene Meriem; Investigation: Imelhayene Meriem, Saidj Dahia, Hadbaoui Ilyes, Senoussi Abdelhakim; Writing - Original Draft Preparation:

Imelhayene Meriem, Saidj Dahia; Writing - Review And Editing: Hadbaoui Ilyes, Senoussi Abdelhakim; Supervision: Adamou Abdelkader, Saidj Dahia; Data Curation: Imelhayene Meriem; critical revision: Hadbaoui Ilyes, Senoussi Abdelhakim, Saad ahmed, Validation: all authors.

Conflict of Interest

The authors declare no competing interests.

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