EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology, 2026, 27(5), 217–227
https://doi.org/10.12912/27197050/220269
ISSN 2719–7050, License CC-BY 4.0

Received: 2026.03.12
Accepted: 2026.04.15
Published: 2026.05.01

Study of the spatio-temporal dynamics of land use in the Haddad area of Mauritania between 2017 and 2022

Oumou Aly Djibril Dia[1,2*], Mohamed Lemine Babe[1,3], Mamadou Idy Diop[1,3], Mohamed Mahmoud Abidine[1,3], Abdessadeq Boudjaj[2], Laila Rhazi[2], Ahmedou Soule[1,3], Ahmedou Vadel Salihi[1], Moukrim Said[2]

[1] Biodiversity and Valorization of Biological Resources Unit, Faculty of Science and Technology, Nouakchott University, Mauritania
[2] Research Center of Plant and Microbial Biotechnologies, Biodiversity and Environment, Laboratory of Botany and Valorization of Plant and Fungal Resources, Department of Biology, Faculty of Sciences, Mohamed V University in Rabat, Morocco
[3] Mauritania Ecology and Biodiversity Research Unit, Graduate School of Higher Education Nouakchott, Mauritania
* Corresponding author's e-mail: oumsdia29@gmail.com

ABSTRACT

In this research, we studied the spatiotemporal evolution of land use in the Haddad region of Mauritania from 2017 to 2022. The objective was to identify the observed transformations regarding vegetation cover and land use categories, as well as to evaluate their responses to climatic fluctuations and human constraints. This research was inspired by a lack of in-depth knowledge about plant resilience and changes in vegetation cover in this underexplored Sahelian-Sudanese area. We assumed that the various land use categories would display specific transformation patterns, with forest cover and economically valuable species demonstrating superior resilience compared to crops and bare lands. High-resolution satellite images from the Landsat and Sentinel missions, combined with an NDVI study and on-site verification, resulted in the classification of land use into four main classes : trees, crops, pastures, and bare soil. This study of the temporal evolution of these categories was conducted based on image categorization, NDVI trends, and transition matrices. This allowed us to assess the changes in area and coverage rate for each type of land use. The study revealed that the Haddad area is essentially composed of grasslands, while forest cover, initially low, saw a 122% increase during the examined period. On the other hand, areas dedicated to agriculture and cleared soils have seen a respective decrease of -42% and -28%. Species of great economic and ecological interest, such as Ziziphus mauritiana, Combretum glutinosum, and Pterocarpus erinaceus, show signs of rehabilitation and growth, thus demonstrating remarkable plant resilience. Research has also shown that changes in land use are the result of a mix of climatic factors, such as fluctuations in precipitation, and human interventions like agriculture and livestock farming. This study proposes a first in-depth quantitative assessment of the spatiotemporal dynamics of land use in the Haddad region, providing new insights into vegetation regeneration, land cover changes, and the specific responses of species. This study offers a first in-depth quantitative assessment of the spatio-temporal dynamics of land use in the Haddad region, providing new insights into vegetation regeneration, land cover changes, and the specific responses of species. The approach used, which combines satellite imagery, NDVI measurement, and field verification, provides a reproducible model that can be applied to other Sahelo-Sudanese ecosystems.

Keywords: land use, regeneration, remote sensing, degradation, Haddad.

INTRODUCTION

Rural communities in Africa rely heavily on agricultural products, including forest resources, which are vital sources of income, food, and medical supplies. (Rabiou et al., 2017). Because of this dependence, rural communities are particularly vulnerable to environmental changes. The

Sahelian countries, including Mauritania, are facing increasing soil degradation as a result of both climate change and human pressures such deforestation, deforestation, agricultural practices that are not sustainable, and deforestation (Gansaonré, 2018; Maukrim et al 2026, Rabiou et al., 2015). Current challenges have worsened the depletion of natural resources during the past few decades, decreasing both the availability of ecosystemic services and the productivity of local means of subsistence (BA et al., 2016). The nation experiences a hot climate with elevated temperatures and is especially susceptible to climate change impacts. This susceptibility is worsened by insufficient rainfall, soil deterioration, and increased fragility in its ecosystems and their processes (BA et al., 2016). Monitoring changes in land use is crucial to understanding the relationship between human activity and ecosystem dynamics. The detection is an effective tool for ongoing terrestrial cover observation, enabling the creation of high-resolution spatiotemporal data sets that can track changes in ecosystems over time (Kpedenou et al., 2017; Nadège et al., 2023) Despite the increasing use of satellite imagery for studies on the use of land in the Sahel, there are few recent and small-scale analyses that focus specifically on the region of Haddad in Mauritania, which is known for its rich biodiversity and the significant reliance of local communities on forest products. There is a gap in the understanding of the detailed spatiotemporal dynamics of land use at the local level since existing data frequently provide regional assessments or obsolete data sets.

In order to fill this gap, the study looks at the spatiotemporal dynamics of land use in the Haddad region of Mauritania between 2017 and 2022. The research is directedtowards:

- Using satellite imagery to create detailed maps of land use for the years 2017–2022,
- quantifying and evaluating the changes in the land use plans, and
- to determine the main causes of these changes, as well as any potential connections between anthropogenic and climatic factors.

Research hypotheses and expected results:

- H1: During the analyzed period, Haddad experienced notable changes in land use, mainly due to human actions and exacerbated by climatic fluctuations.
- H2: Spatial models of land use transformation reveal previously unquantified dependencies between the availability of forest resources and local livelihoods. The study, by verifying these assumptions, seeks to enrich our understanding of local land use dynamics and ecosystem vulnerability. It thus aims to provide guidelines based on solid evidence for the preservation and sustainable management of resources.

MATERIALS AND METHODS

Study area

The study focuses on the Haddad region, integrated into the municipality of Beilouguet Litame, within the moughata of Mahagma in the Gorgol region, in the south of Mauritania. It extends between 16°03′ north latitude and 12°49′ west longitude (Figure 1) It covers an area of 13,600 km² and is bounded by Assaba (N, NE), Guidimakha (S, SE), Brakna (NW), and the Senegal River (SW) (ONS, 2016). The Haddad area, which is part of the El Atf ecosystem, is considered an exceptional biotope characterized by rich biodiversity with potential regenerative capacitie (Unesco,2020). Haddad is located in the climatic region of the southern Sahel, where annual precipitation ranges from 149 to 635 mm and temperatures fluctuate between 16–25 °C (min) to 31–42 °C (max) depending on the month (Agadir, 2011, ONM). The rainy season lasts from May to November. The soils have a sandy composition, with a slight presence of silt at depth, and support a tall shrub steppe. The area is characterized by agro-pastoralism, with nomadic herding during the dry season, and agriculture, which constitutes the main subsistence activity (Agadir, 2011). According to the results of the 2013 General Population and Housing Census (RGPH), the population of the El Atf area is 96,895, comprising 46,899 men and 49,996 women, representing 48.40% and 51.60% of the population respectively. The Haddad area is characterized by sandy substrate, slightly silty at depth. A tall shrub steppe grows there (BA et al., 2016). It belongs to the southern Sahelian climate zone and species from the Sudanian domain grow there (BA et al., 2016). This is an agro-pastoral region where nomads travel with their herds during the dry season, providing important environmental and socio-economic services. Agriculture and livestock farming are the main income-generating activities.

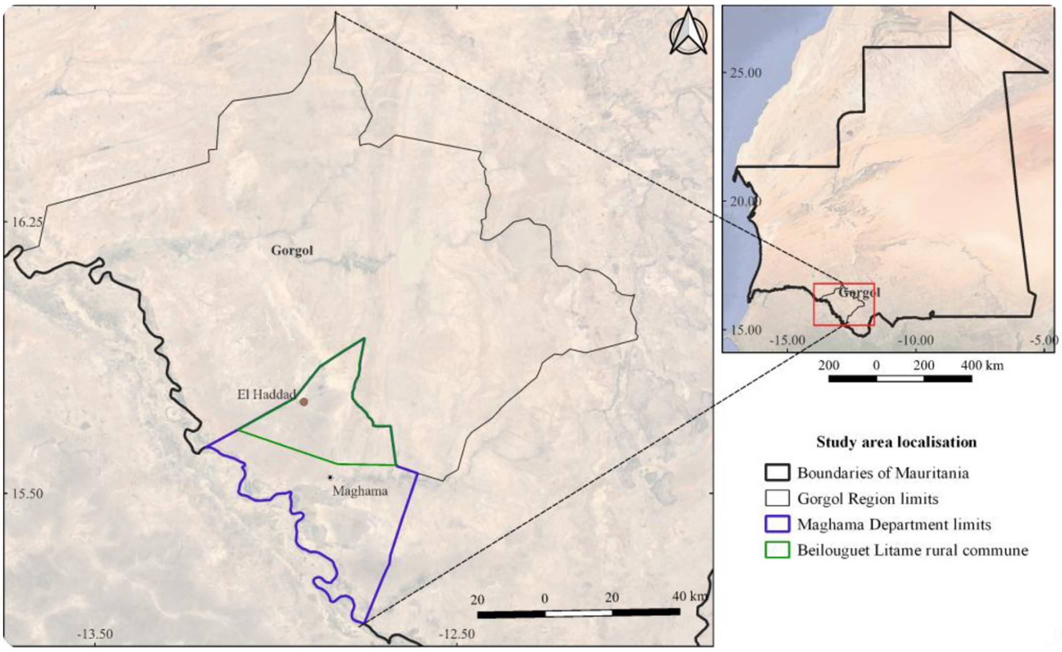

Figure 1. Location of the study area (Dia et al., 2026)

Monitoring land use trends and dynamics

Land use dynamics can be defined as the evolution of land use classes over time and space, either towards a state of degradation or improvement, or towards a more or less stable equilibrium, accounting for all spatial and temporal variability (Taibou and Seck, 2012). This dynamic makes it possible to synthesize the changes in land use classes that have occurred in the same landscape at different periods (Biga et al., 2020). The methodological approach used to analyze land use dynamics combines traditional geomatics methods with data mining techniques, drawing on a wide range of sources and key time horizons (El Madihi et al., 2023).

Satellite data and data sources

Land use dynamics were analyzed using two complementary but distinct satellite data sources, each serving a specific analytical purpose. For NDVI time series analysis, three Landsat missions were mobilized to cover the full study period via Google Earth Engine (GEE), all from Collection 2 Tier 1 Surface Reflectance: Landsat 5 TM (LANDSAT/LT05/C02/T1_L2, 1985–1998), Landsat 7 ETM+ (LANDSAT/LE07/C02/T1_L2, 1999–2013), and Landsat 8 OLI/TIRS (LANDSAT/LC08/C02/T1_L2, 2014–2023). Images were filtered using a cloud cover threshold of less than 2% and clipped to the study area boundary. Surface reflectance values were rescaled prior to any computation by applying the standard USGS Collection 2 scale factor (× 0.0000275 + −0.2). The three collections were subsequently merged into a single time series for NDVI computation and temporal analysis.

For land use classification, annual 10 m land cover composites were sourced from the ESRI LULC10 dataset (Impact Observatory), a pre-classified product derived exclusively from Sentinel-2 imagery and distributed through GEE. This dataset is available annually from 2017 onwards, making it fully suitable for the 2017–2022 study period. Raw Landsat imagery is freely accessible via USGS Earth Explorer (https://earthexplorer.usgs.gov), and Sentinel-2 products via the Copernicus Open Access Hub (https://scihub.copernicus.eu).

Image preprocessing

Landsat 8 Surface Reflectance values were rescaled prior to any computation by applying the standard USGS Collection 2 scale factor (× 0.0000275 + −0.2). Images were filtered using a cloud cover threshold of less than 1% based on scene-level metadata (CLOUD_COVER < 1), yielding a final collection of 310 scenes. All images were subsequently clipped to the Haddad study area boundary. The ESRI LULC10 product required no additional preprocessing, as it is distributed as an analysis-ready, atmospherically corrected dataset processed using Sen2Cor (Sentinel-2 Level-2A).

Vegetation monitoring, NDVI time series

To monitor vegetation condition and identify spatial and temporal changes caused by anthropogenic and natural disturbances, the Normalized Difference Vegetation Index (NDVI) was computed following Rouse et al. (1973):

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

and designations differ between sensors: for Landsat 5 TM and Landsat 7 ETM+, NIR corresponds to SR_B4 and Red to SR_B3; for Landsat 8 OLI, NIR corresponds to SR_B5 and Red to SR_B4. Mean NDVI values were extracted by region using ee.Reducer.mean() at 30 m spatial resolution, generating a multi-temporal time series spanning 1985–2023. The index was calculated for each of the 310 scenes in the collection using GEE mapping functions, generating a multi-temporal NDVI stack over the 1985–2022 period.

Precipitation data from the National Meteorological Office (2001–2022) were integrated to contextualize seasonal vegetation dynamics and assess vegetation resilience to climatic conditions.

Land use classification

Four land use classes were defined based on their ecological and socioeconomic relevance to the Haddad area: (i) *Trees*: areas dominated by tree canopy cover; (ii) *Crops*: rain-fed agricultural land; (iii) *Rangeland*: areas of sparse or herbaceous vegetation; and (iv) *Bare Ground*: soils with minimal or no vegetation cover. These classes were extracted from the ESRI LULC10 annual composites for 2017 and 2022 by remapping the original nine-class scheme to the four selected classes in GEE. The ESRI LULC10 classification is based on a supervised deep learning approach trained on globally distributed reference samples derived from high-resolution imagery, achieving a reported overall accuracy exceeding 85% at global scale. Classified images were exported at 10 m spatial resolution for cartographic processing in QGIS 3.28.

Change detection

Land use change between 2017 and 2022 was assessed by pixel-level comparison of the two classified images. A transition layer was computed using the following encoding:

$$LULC_{Change} = (LULC_{2022} \times 10) + \\ + LULC\_2017$$

This approach generates a unique code for each possible class transition, enabling systematic identification of stable areas (same class at both dates) and transitional areas (class change between 2017 and 2022). Area statistics were calculated for each class and each transition type to quantify the magnitude and direction of land use changes, expressed in absolute area (ha) and relative change (%) per class. After, Class transition matrices were produced to summarize changes between classes.

Tools and software

All satellite image processing, NDVI computation, and land use change were performed using Google Earth Engine (GEE, JavaScript API). Cartographic outputs, results analysis and spatial visualization were produced in QGIS 3.28. A conceptual workflow diagram summarizing the analytical steps from data acquisition to change quantification is presented in Figure 2.

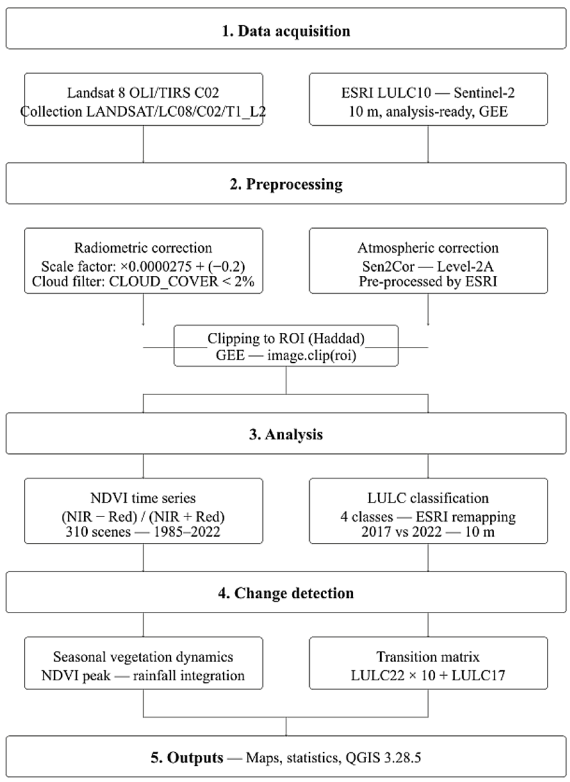

Figure 2. Methodological for NDVI time series analysis and LULC change detection in the Beilouguet Litame municipality, Mauritania

RESULTS

With advances in modern detection technologies and satellite scanning algorithms, geostationary and polar orbiting satellites are widely used to meet various needs in several fields, including environmental monitoring, land use analysis, and observation of the impacts of climate change in a region. Our findings reveal the evolution of land use in the Haddad region during this period.

Analysis of changes in precipitation and vegetation index

Precipitation

Figure 3 shows the evolution of precipitation between 2001 and 2022. Our results indicate that the Haddad region has undergone various changes in terms of precipitation from one year to the next. However, recent years have been marked by a decline in precipitation, which has. This can be seen on the land cover maps of the area between 2017 and 2022. Regeneration characterized by low, medium, and high percentages can be observed, as shown in the transition matrix.

NDVI

The growth of the vegetation index is shown in Figure 4. Index values vary annually, with a general upward trend since 2012. Average INDV index values range from 0.23 to 0.37, respectively. However, over the last decade, a slight increase in precipitation has been recorded during the months of June, July, August, September, and October. It should be noted that this region regularly receives a significant amount of precipitation each year, which has a considerable influence on the dynamics of the vegetation and its regeneration processes. The results clearly show that this region experienced significant rainfall, which promoted the regeneration of plant taxa, including *Pterocarpus erinaceus*, *Ziziphus mauritiana*, and *Combretum glutinosum*.

Spatio-temporal dynamics of land use between 2017 and 2022

Hadad's geographical location is one of the main factors that give it a unique flora profile compared to other surrounding regions. Nevertheless, climatic conditions are characterized by the Sahelo-Sudanese classification, with annual rainfall reaching up to 650 mm, which promotes the proliferation of specific plant taxa and encourages the development of a wide variety of flora in the region, including species with considerable water requirements. Consequently, rainfall levels in the Sahelian and Sahelo-Sudanese zones fluctuate between 150 and 600 mm. Our results show that this region has experienced a significant change in rainfall over the last few decades, which is beneficial for vegetation.

Land use mapping

After identifying and spectrally recognizing land use classes based on different images, correspondence checks were also carried out using Google Earth Pro and ESA archive images, and a field mission was even conducted to more

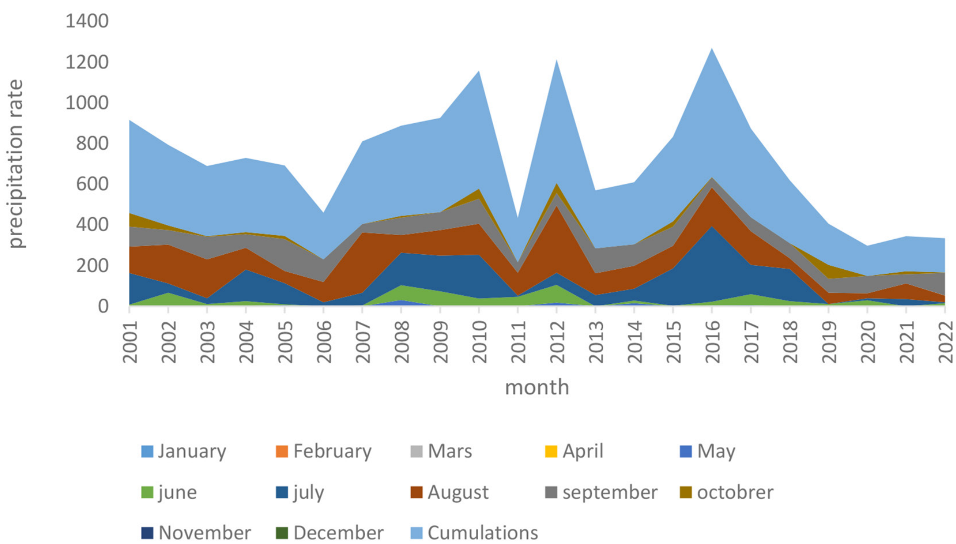

Figure 3. Annual rainfall in the study area

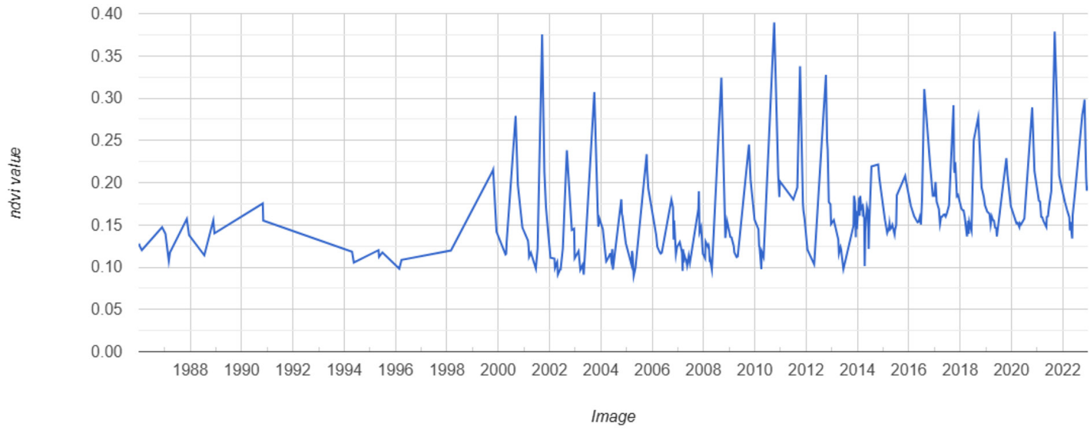

Figure 4. NDVI Evolution in the study area over the period 1985–2022

accurately distinguish the following vegetation units within the different classes:

The tree class "Trees" is characterized by the species most commonly found in this area: Ziziphus mauritiana 25.6% (12.53 individuals/ha), Combretum glutinosum 15.8% (7.73 individuals/ha), *Guierra senegalensis* 11.2% (5.47 individuals/ha), *Pterocarpus erinaceus* 8.4% (4.13 individuals/ha), *Boscia senegalensis* 5.1% (2.53 individuals/ha) and *Balanites aegyptiaca* 3.8% (1.87 individuals/ha). These six species account for 70.2% of the total population density. *Vachellia tortilus*, *Vachellia siebriana, vachelia seyal*, *senegalia senegal*, and *Hexabolus monopetalis*.

It is also characterized by the presence of natural forests of Ziziphus mauritiana, Combretum glutinosum, Bosia senegalensis, Guiera senegal, and Balanites aegyptica. The study area is rich in varied and abundant flora. It is distinguished by a layer of trees and shrubs whose height varies according to species. There is also herbaceous cover, generally annual.

The crops class consists exclusively of cereal crops such as sorghum, millet, and corn, which are rain-fed crops.

The "sparse vegetation/rangeland" class includes areas with degraded vegetation dominated by *Tamarindus indica*, *Grewia bicolor*, and *Vachelia nilotica* with low coverage rates, lakes covered with a little pasture.

Bare ground classes are classes of bare soil that are essentially deserts.

The land cover maps for 2017 and 2022, derived from satellite image classification, are illustrated in Figures 4 and 5. For 2017, the map (Figure 4) clearly shows the dominance of the "Rangeland" class with 759,883,437 m^2 (93.8% of the total area), followed by the "Bare Ground" class with 33,185,990 m^2 (4.1%), then the 'Crops' class with 16,419,802 m^2 (2%), and finally the 'Trees' class with 690,672 m^2 (approximately 0.1% of the total area).

Wooded areas are mainly located in the northeastern parts. For the year 2022, the results of this classification still show the dominance of the "Rangeland" class, which covers an area of approximately 775,583,152 m^2, or about 95.7% of the study area. The remainder is occupied by the 'Bare Ground' class with 23,628,123 m^2 (2.9%), the 'Crops' class with 9,435,434 m^2 (1.2%) and, lastly, the 'Trees' class with 1,533,194 m^2 (0.2%) (Figure 6).

Spatio-temporal evolution of land use

The spatio-temporal evolution of land use in the study area between 2017 and 2022 shows that the four identified land uses have undergone changes. In terms of percentage change, the "Trees" class recorded a significant increase (+122%) compared to the other classes, which underwent a moderate to slight decrease. However, in terms of area, the 'Rangeland' class recorded the most significant change (+15,699,715 m^2), while the 'Trees' class recorded achange in area of around 842,522 m^2. The other classes recorded declines of around -42% for the 'Crops' class and -28.8% for the 'Bare Ground' class.

The superposition of the 2017 and 2022 land cover maps enabled the creation of a map illustrating the land use maps for these two years (Figure 7), This analysis highlights the evolution of plant dynamics, and the spatialization of the changes that occurred. The development of the

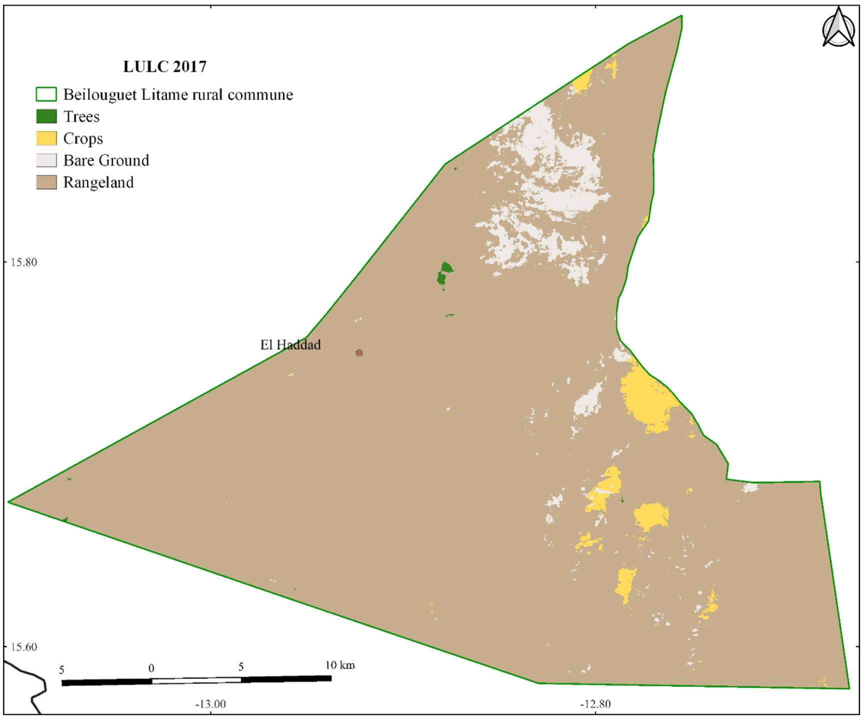

Figure 5. Land use classes in the El Haddad area in 2017

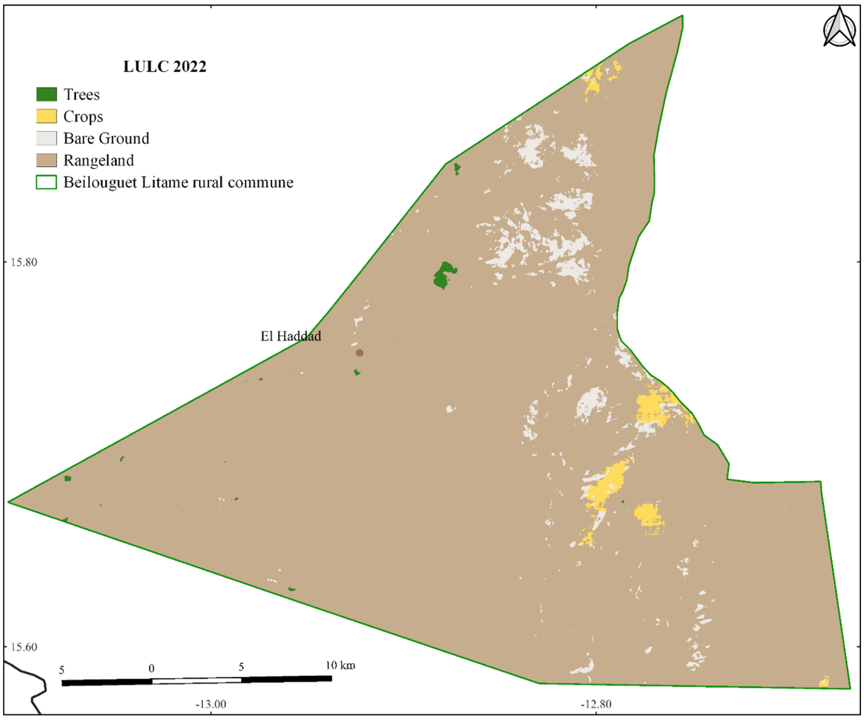

Figure 6. Land use classes in the El Haddad area in 2022

transition matrix revealed the different dynamics and changes in land use classes that occurred during the study period (Table 1). However, analysis of the transition matrix between 2017 and 2022 highlights highly variable levels of stability depending on land use classes. Thus, only 5% of the areas were converted to other classes between the two dates.

The most significant conversions remain those relating to the transition of areas classified as "Bare Ground" and 'Crops' to "Rangeland" (19,053,850 m^2 and 8,429,126 m^2, respectively).

It also highlights that only 68% of the areas classified as 'bare ground' underwent no change during the period 1995–2020. Other notable conversions are worth mentioning, including the conversion of 'Rangeland' to 'Trees' (901,255 m^2) and 'Crops' (2,398,922 m^2).

DISCUSSION

Changes in forest cover are a crucial indicator of the health of ecosystems, simultaneously reflecting climate variability and human-induced constraints. (Ma et al., 2025; Bouchelouche et al., 2022). Our research offers the first in-depth spatio-temporal study of land use in the Haddad region for the period 2017–2022, thus filling a gap in knowledge regarding local vegetation dynamics in this ecologically important area. We noted a 122% increase in forest cover, while the expansion of pastures was moderate and cultivated lands and desert areas decreased. Our results show that this area has experienced periods of regression and progression, as well as periods of conversion and modification. The analysis of the trends in the NDVI index and precipitation showed that, despite significant variations in precipitation from one region to another, the population declined, indicating the ability of species like *Pterocarpus erinaceus*, *Ziziphus mauritiana*, and *Combretum glutinosum* to adapt (Ngom et al., 2013) This partial correlation between the NDVI index and precipitation is consistent with findings in similar Sahélo-Soudanais ecosystems (El Madihi et al., 2023), indicating that local microclimatic and geological conditions, as well as species-specific characteristics, play a significant role in the resilience of deforestation. Changes in precipitation over recent years have promoted vegetation regeneration in the Haddad region, an agro-pastoral area rich in diverse plant species. Our results show a remarkable evolution in the tree class, followed by the sparse vegetation class and a decrease in the crop and bare land classes (see Table 2).

Analysis of the spatio-temporal dynamics of land use in the Haddad region highlighted the possibilities offered by satellite imagery for mapping, modeling, and analyzing changes in land use. Agricultural expansion and overgrazing both seem to contribute to the reduction of cultivated lands and bare soil areas. Human actions, such as selective logging and deforestation, significantly influence vegetation cover and species composition. (É. A. M, 2020; Djohy et al., 2016). Our conclusions highlight that, even in areas under light human pressure, the spatial distribution of land use categories

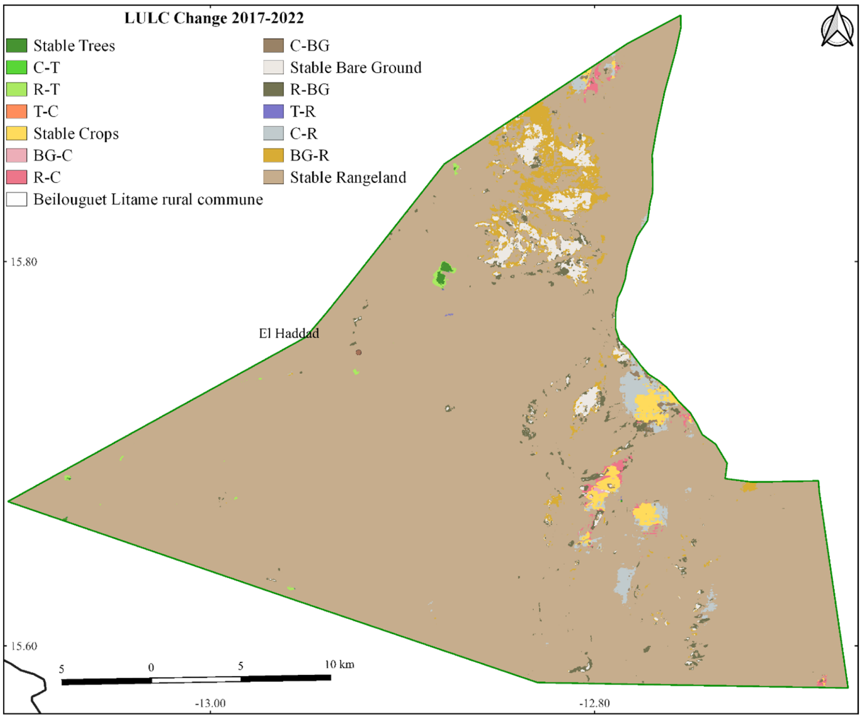

Figure 7. Changes in land use in the El Haddad area between 2017 and 2022

Table 1. Land use changes between 2017 and 2022 in square meters

Parameter	T (m^2)	C (m^2)	BG (m^2)	R (m^2)	Total 2017 (m^2)
Trees	**630315**	287		60071	690672
Crops	1624	**6806352**	1182700	8429126	16419802
Bare ground		229874	**13902266**	19053850	33185990
Rangeland	901255	2398922	8543156	**748040105**	759883437
Total 2022	1533194	9435434	23628123	775583152	810179902

Table 2. Changes in land use in the study area between 2017 and 2022

Parameter	Total 2017	Total 2022	Evolution (%)
Trees	690672	1533194	**+122**
Crops	16419802	9435434	-42.5
Bare ground	33185990	23628123	-28.8
Rangeland	759883437	775583152	**+2.1**
Total	810179902	810179902	

reflects a combination of ecological processes and human management. This phenomenon indicates a transformation of considerable magnitude for the tree and crop classes as well as for sparse vegetation, regardless of the time frame of the study (É. A. M, 2020). Examination of land use mapping covering the period from 2017 to 2022 clarified the gradual progression of specific land use categories during this interval. Assessment of the spatiotemporal dynamics of vegetation revealed the progression of tree and rangeland classes and the regression of crop and bare land classes. The causes of vegetation cover degradation are anthropogenic and can also be climatic when the ecological zone does not receive the minimum rainfall required for spontaneous vegetation regeneration, which is increasingly observed with climate change(Adjonou et al., 2010).

Although natural factors may contribute to the decline of natural environments (Wang et al., 2014), Increased anthropogenic pressures, particularly those related to this, largely explain this downward trend observed in the steppes. The steppes of North Africa are distinguished by their diversity, which gives them an essential socio-economic role and important ecological functions for the conservation of natural resources (El Madihi et al., 2023).

They constitute a major regional heritage, not only because of the vast area they cover, but also because of the wealth of treasures they contain, which is one of the main sources of livelihood for local populations (El Madihi et al., 2023). However, this decline in natural vegetation is accompanied by a loss of biodiversity and land degradation. The high population density in this area (agropastoral) is also one of the causes of the degradation of these natural vegetation formations. The flora of Haddad includes species that have great medicinal, industrial, and economic value, widely used by local communities. Changes in land use and vegetation cover have a direct impact on local sources of income, highlighting the need for sustainable management. The remarkable increase in forest cover could signal an ongoing regeneration process; however, the decrease in cultivated areas and unused land suggests a possible pressure on agricultural productivity and forage supply. The remarkable increase in forest cover could signal an ongoing regeneration process; however, the decrease in cultivated areas and unused lands suggests a possible pressure on agricultural productivity and forage supply. It is therefore crucial to establish regulatory structures for the preservation and management of soils in order to maintain ecological and socio-economic resilience (Gansaonré, 2018). In consequence it is an urgency to establish a regulated framework for the sustainable management and protection of these vital natural resources. This research highlights the feasibility of using satellite imagery, NDVI analysis, and field validation to observe the small-scale spatiotemporal dynamics of land use in a region that has not yet been extensively explored. The transition matrix provides recent quantitative information on trends related to vegetation modification and land use transformation, highlighting the links between natural regeneration, human influences, and species-specific responses.It would be relevant to include socio-economic studies and forecasting models in future research to deepen the understanding of the elements that cause changes in land use, and to guide sustainable management strategies in the Sahelo-Sudanese zone.

CONCLUSIONS

The current study reveals that the Haddad area is predominantly dominated by pasture lands. The analysis led us to determine that starting from an initially low tree cover, a notable growth of 122% occurred during the period 2017–2022. The lands dedicated to agriculture and exposed soil areas experienced a respective decrease of 42% and 29%. These conclusions corroborate our assumption that vegetation types respond distinctly to natural and human factors, with forest cover showing remarkable resilience and natural regeneration even in the presence of variations in precipitation. It has been observed that the most widespread plants, such as Ziziphus mauritiana, Combretum glutinosum, and Pterocarpus erinaceus, are recovering and expanding in areas previously designated as pastures or degraded lands. This supports the second hypothesis which indicates that certain species with economic and ecological value can survive, or even thrive, despite climatic variations and human constraints. Using satellite images and NDVI analysis to quantify land use changes, we have managed to detect patterns of vegetation modification never before observed in the Haddad region. This sheds new light on the dynamics of Sahelo-Sudanese agro-pastoral ecosystems. Overall, the study successfully mapped land use transformations and examined their dynamics over time and space, demonstrating that the region is characterized by simultaneous processes of degradation and regeneration. The discoveries provide unprecedented information on vegetation resilience, land cover changes, and species-specific responses, which had not been previously defined for this area.

Acknowledgments

The authors are deeply grateful to the Laboratory of Botany and Valorization of Plant and Fungal Resources, Department of Biology, Faculty of Sciences, Mohamed V University in Rabat, for facilitating the research stay of Oumou Aly and for the invaluable academic accompaniment provided at every stage of this work, from conceptualization and methodology to results analysis and manuscript writing.

REFERENCES

1. Adjonou, K., Djiwa, O., Kombate, Ad Kokutse, Y., Kokou. K. (2010). Study of the spatial dynamics and structure of the dense dry relic forests of Togo: implications for sustainable management of protected areas. *International Journal of Biological and Chemical Sciences 4*(1). https://doi.org/10.4314/ijbcs.v4i1.54242
2. Ba, A., Kane, G., Sall, M., Barry, O. (2016). Rapport d'Evaluation de la situation de Reference des paysages selectionnes.
3. Bouchelouche, A., Hani, M., Rafika, L. (2022). Spatio-temporal dynamics of vegetation cover in semi-arid zones: Forest of djebel boutaleb (Algeria). *Algerian Journal of Arid Environment*, 15–27.
4. Djohy, G.L., Vodounon, H.S.T., Kinzo, N.E. (2016). Dynamics of land use and Evolution of agricultural lands in the municipality of sinende in northern benin *Cahiers du CBRST*, nº 9: 101–21.
5. El Madihi, M.E., Moukrim, S., Lahssini, S., et al. (2023). Vegetation dynamics of North African steppe (case study of the Moulouya plateau in Morocco). Ekologia (Bratislava), 42(4), 354–361. https://doi.org/10.2478/EKO-2023-0040
6. Fao (2011). Presentations from the Regional Meeting on Spate Irrigation. Agadir. https://floodbased.org/documents/library/agadir-2011/
7. Gansaonré, R.N. (2018). Dynamics of vegetation cover and socio-environmental implications on the periphery of park W/Burkina Faso. *VertigO*, 18(1). https://doi.org/10.4000/vertigo.20249
8. Kpedenou, K.D., Drabo, O., Ouoba, A.P., Da, D.C.E., Tchamie, T.T.K. (2017). Analysis of land use for monitoring landscape evolution in the Ouatchi territory in southeastern Togo between 1958 and 2015 *Cahiers Du Cerleshs* XXXI (55), 203–28.
9. Ma, E., Feng, Z., Chen, P., Wang, L. (2025). Spatio-temporal dynamics of forest vegetation in Northern China and their responses to climate change. *Forests* 16(4): 671. https://doi.org/10.3390/f16040671
10. Moukrim, S., Lahssini, S., Menzou, K., Benabbou, A., Boudjaj, A., Bammou, M. B., ... & Rhazi,

L. (2026). Vulnerability and projected dynamics of north African forest ecosystems under climate change. In: Forest Vulnerability and Climate Risk Assessment: Dynamics, Disturbances, and Resilience (pp. 1-26). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-2600-0783-9.ch001

11. Nadège, K., Vincent, O., Akokponhoue, B.H. (2023). Contribution of remote sensing and GIS to the mapping of land use units and its changes in the face of the flooding problem on the plateau of Allada in Benin between 1986 and 2020. *International Journal of Innovation and Scientific Research*, 65(2), 164–77.
12. Ngom, D., Fall, T., Sarr, O., Diatta, S., Akpo L.E. (2013). Ecological characteristics of the woody vegetation in the Ferlo Biosphere Reserve (Northern Senegal). *Journal of Applied Biosciences 65*(0). https://doi.org/10.4314/jab.v65i0.89644
13. ONS. (2016). Regional monograph of the Gorgol wilaya. Administrative report. Mauritanie.
14. Rabiou, H., Diouf, A. Bationo, B. et al. (2015). Demographic structure of natural populations and spatial distribution of *Pterocarpus erinaceus* Poir. seedlings in the forest. *International Journal of Biological and Chemical Sciences 9*(1), 69. https://doi.org/10.4314/ijbcs.v9i1.7
15. Rabiou, H., Bationo, B.A., Adjonou, K., Kokutse, A.D., Mahamane, A. (2017). Peasant perception and sociocultural and ethnobotanical importance of *Pterocarpus erinaceus* in Burkina Faso and Niger. *Afrique Science*, 13(5), 43–60.
16. Tchibozo, É. A. M. (2020). Modeling the spatio-tem- poral dynamics of land occupation and analyzing territorial changes in Lama, Benin. European Scientific Journal, 16(6). https://doi.org/10.19044/esj. 2020.v16n6p499
17. Wang, S., Huang, J., He, Y., Guan, Y. (2014). Combined effects of the pacific decadal oscillation and El Nino-southern oscillation on global land dry-wet changes. *Scientific Reports*, 4, 6651. https://doi.org/10.1038/srep06651
18. https://meteomauritanie.mr/
19. https://floodbased.org/documents/library/agadir-2011/
20. https://ghdx.healthdata.org/record/mauritania-population-and-housing-census-2013