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# SET-ASIDES AS A GOVERNANCE INSTRUMENT FOR SUSTAINABLE MANAGEMENT OF STEPPE ECOSYSTEMS: CASE OF TIARET REGION (ALGERIA)

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**Abstract**
Land degradation in steppe ecosystems represents a major environmental and governance challenge in arid and semi-arid regions. In Algeria, overgrazing, weak regulation of pastoral practices, and increasing climate variability have accelerated ecosystem degradation. This study examines *set-asides* (*mise en défens*) as a governance-based land management instrument aimed at restoring degraded steppe ecosystems while balancing ecological sustainability and socio-economic needs. Focusing on the steppe zones of Tiaret Province (Ain Dheb, Chehaima, and Naima) over the period 2018–2022, the study integrates institutional data, field observations, and spatio-temporal analysis based on the Normalized Difference Vegetation Index (NDVI) to evaluate the ecological and governance outcomes of grazing exclusion policies. Rather than merely assessing vegetation cover, NDVI is used as an indicator of ecosystem response to regulatory interventions and grazing pressure control. The results show that set-asides contribute to improved vegetation dynamics, reduced grazing pressure, and enhanced territorial regulation through controlled access mechanisms. However, their long-term effectiveness remains contingent upon participatory governance, enforcement capacity, and alignment between livestock numbers and ecological carrying capacity. The findings highlight the central role of adaptive land governance in combating desertification and promoting sustainable land management in dryland contexts.

**Keywords:** set-asides; land governance; steppe ecosystems; NDVI; desertification; Tiaret; Algeria.

## 1. Introduction

Steppe ecosystems in North Africa constitute complex socio-ecological systems that have historically supported extensive pastoralism while remaining highly sensitive to climatic variability and anthropogenic pressure (Le Houérou, 1995; 2001). In Algeria, steppes cover vast areas of the High Plateaus and play a strategic role in national livestock production, rural livelihoods, and food security (Hammouda & al., 2019). Despite their importance, these ecosystems have undergone general degradation over recent decades.

Land degradation in Algerian steppes is expressed through declining vegetation cover, soil erosion, biodiversity loss, and reducing the forage productivity (Saifi & al., 2016).

These processes result from the interaction of multiple drivers, including chronic overgrazing, sedentarization of pastoral communities, agricultural expansion, and weak enforcement of rangeland regulations. Climate change has further exacerbated degradation dynamics by increasing drought frequency and rainfall variability (FAO, 2019; UNCCD, 2021).

In this context, set-asides have emerged as a central management tool to mitigate overgrazing, one of the most critical pressures affecting steppe ecosystems. By temporarily or permanently excluding grazing from degraded areas, set-asides aim to promote natural vegetation regeneration, enhance ground cover, and restore ecosystem resilience. Empirical evidence from the Maghreb and the Sahel demonstrates that set-asides can effectively initiate vegetation

recovery and soil stabilization under arid and semi-arid conditions (Le Houérou, 2001; FAO, 2019). In Algeria, their implementation in steppe regions such as Tiaret has been associated with increased vegetation density and reduced grazing-induced soil degradation (Hammouda & al., 2019).

Steppe vegetation in Tiaret has been shown to respond sensitively to changes in grazing management and land cover dynamics, as evidenced by spatial analyses using remote sensing and GIS techniques (Azzaoui et al., 2018; Bouacha, 2019).

Beyond their ecological function, set-asides also represent a key land governance instrument, through which the state regulates access to common-pool rangeland resources and mediates relationships between public authorities and pastoral communities. Under the supervision of the High Commission for Steppe Development (HCSD), set-asides have become a cornerstone of national strategies for steppe restoration. However, despite their general application, their effectiveness remains uneven and insufficiently assessed, particularly with regard to spatial variability, institutional enforcement, and long-term ecological outcomes.

Against this background, this study addresses the following research question: To what extent do state-led set-asides function as effective land governance instruments for restoring steppe ecosystems, while regulating pastoral pressure in Algeria? By combining spatial analysis of vegetation dynamics with an assessment of grazing regulation, this research aims to contribute to a better understanding of the socio-ecological performance of set-aside policies in semi-arid rangelands.

## 2. Objectives of the Study

The main objective of this study is to assess the effectiveness of set-asides as a land governance instrument for the restoration and sustainable management of steppe ecosystems in the Tiaret region (Algeria), by integrating ecological indicators derived from NDVI analysis with an evaluation of grazing regulation practices.

More specifically, the study aims to:

1. Analyse the spatio-temporal dynamics of vegetation cover between 2018 and 2022 in set-aside and grazed areas using NDVI-derived indicators ;
2. Assess the ecological response of steppe vegetation to grazing exclusion, with particular attention to vegetation recovery and stability ;
3. Examine the relationship between grazing pressure, livestock density, and vegetation dynamics in the communes of Ain Dheb, Naima, and Chehaima ;
4. Evaluate the institutional role of set-asides in regulating access to rangeland resources and managing pastoral pressure ;
5. Identify key ecological and governance-related constraints that limit the long-term effectiveness of set-aside policies ;
6. Provide science-based recommendations to support adaptive and participatory rangeland management strategies for the sustainable restoration of Algerian steppe ecosystems.

## 3. Study Area

Tiaret Province, located in the Algerian High Plateaus, constitutes a representative region for the study of semi-arid steppe ecosystems. The present study focuses on three steppe municipalities (Ain Dheb, Naima, and Chehaima) situated within the Daïra of Ain Dheb, where agropastoral systems dominate land use.

Geographically, Tiaret lies between latitudes 34°30'N and 36°N and longitudes 1°E and 2°30'E, with an average altitude ranging from 800 to 1508 meters. The region is characterized by a semi-arid climate, characterized by cold winters and hot, dry summers, with an annual average rainfall between 300 and 400 mm (ONM, 2020).

The analysis focuses on three steppe communes in the the Daïra of Aïn Dheb: Aïn Dheb, Naima, and Chehaima. These communes, dominated by agropastoral systems, contain several

designated fallow areas. The vegetation is primarily adapted to arid conditions, with species such as *Stipa tenacissima*, *Artemisia herba-alba*, *Lygeum spartum*, and halophytic species such as *Atriplex halimus* (Bouazza & al. 2004). These areas are essential for local socio-economic activities, particularly extensive livestock farming, but they are highly vulnerable to soil degradation and overgrazing (Hammouda & al., 2019).

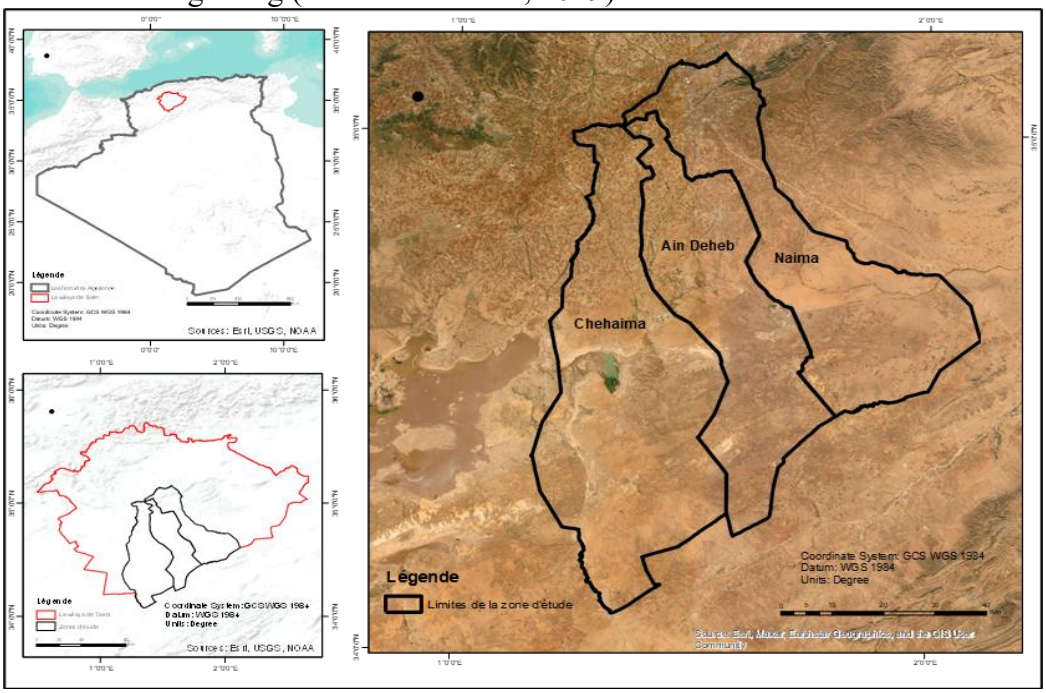


**Figure 1:** Location of the Tiaret Region and the study municipalities (Ain Dheb, Naima, Chehaima).

**Source:** Map produced by the authors based on field data

The Ain Dheb region, located in the steppe zone of the Tiaret province, exhibits significant ecological diversity despite its semi-arid climatic constraints. The vegetation of Ain Dheb is typical of Algerian steppes, dominated by formations of *Stipa tenacissima* (esparto grass), *Artemisia herba-alba* (white wormwood), and *Lygeum spartum* (needlegrass). These species play a critical ecological role in combating soil erosion and regulating hydrological cycles. The azonal flora includes psammophilous species (adapted to sandy soils) such as *Calligonum comosum* and halophilous species (tolerant of saline soils) like *Atriplex halimus*, which thrive in specific habitats (Bouazza & al., 2004).

## 4. Methodology

### 4.1 Research Design and Governance Approach

This study adopts an integrated methodological framework combining ecological assessment and governance analysis. The research design is based on a longitudinal analysis (2018–2022) to capture temporal dynamics in set-aside management, grazing regulation, and vegetation response. Set-asides are analyzed as governance instruments regulating access to common-pool rangeland resources under state supervision (Ostrom 1990).

### 4.2 Selection of Study Stations

The study area was selected within the Daïra of Ain Dheb, which includes three major steppe municipalities: Ain Dheb, Naima, and Chehaima. These municipalities host several officially designated set-aside perimeters, making them particularly relevant for evaluating governance effectiveness. The selection of stations was based on the following criteria:

- Total surface area of each perimeter (ha);
- Surface area temporarily or permanently open to grazing (ha);
- Livestock numbers (sheep and goats) authorized per perimeter;

- Duration and mode of set-aside implementation.

Within Ain Dheb, the perimeters of Reyacha El Hamra, El Alibait and Megcem Elhalais were studied. In Naima, the protected perimeter of Mekimen was selected, while in Chehaima the stations of Hafsa 01, Si Ziane and Dhaya El Khadra were analyzed.

### 4.3 Data Collection

Data collection combined documentary analysis, field surveys, and institutional records. Official data were obtained from the Directorate of Agricultural Services (DAS) of Tiaret Province and the High Commission for Steppe Development (HCSD), covering the period from 2018 to 2022. These data included information on grazing authorizations, livestock numbers, perimeter boundaries, and management rules.

Field surveys conducted in spring and autumn focused on vegetation cover and indicators of grazing pressure.

### 4.4 Data Analysis

The Normalized Difference Vegetation Index (NDVI) derived from satellite imagery was used to assess vegetation dynamics over time. Geographic Information Systems (GIS) enabled spatial analysis of grazing areas and set-aside perimeters. Statistical analysis was applied to examine relationships between vegetation composition, environmental variables, and grazing intensity.

## 5. Results

### 5.1 Evolution of Set-Aside and Grazing Areas (2018–2022)

As illustrated in Figure 2, the comparison between total set-aside perimeters and areas authorized for grazing in the stations of Ain Dheb (Megcem Elhalais and Reyacha El Hamra sectors), Naima (Mekimen sector), and Chehaima (Si Ziane and Poste Hafsa 01 sectors) over the period 2018–2022 reveals pronounced spatial and temporal dynamics in grazing management.

In 2018, Figure 2.A shows that grazing areas represented a substantial proportion of the total perimeters across all three stations. Ain Dheb covered approximately 40,200 ha of set-asides, of which about 28,550 ha were open to grazing, while Naima exhibited 19,650 ha of grazing land within a 35,000 ha perimeter. Chehaima displayed the highest relative grazing intensity, with 9,150 ha open to grazing out of a total of 13,000 ha. This configuration reflects a management phase characterized by controlled but relatively permissive grazing, aimed at maintaining pastoral activities while limiting excessive pressure.

According to Figure 2.B, this pattern persisted into 2019, with moderate expansions of grazing areas in Naima (26,600 ha) and Chehaima (14,637 ha within a 15,937 ha perimeter), while Ain Dheb remained relatively stable (28,804 ha open to grazing out of 40,254 ha). These variations indicate short-term adjustments in grazing authorization rather than structural changes in land management.

A clear turning point is visible in Figure 2.C in 2020, when total perimeters and grazing areas became equivalent in the three stations (40,200 ha in Ain Dheb, 35,000 ha in Naima, and 13,000 ha in Chehaima), suggesting a transitional phase preceding stricter regulatory intervention.

From 2021 to 2022, Figure 2.D.E highlights an abrupt contraction in grazing areas, particularly in Ain Dheb and Naima. In Ain Dheb, grazing surfaces collapsed to 254 ha in 2021 and further to approximately 200 ha in 2022, representing the most severe reduction observed during the study period. Naima followed a comparable trajectory, with grazing areas reduced to 3,500 ha in 2021 and complete exclusion in 2022. In contrast, Chehaima remained remarkably stable, maintaining approximately 13,000 ha open to grazing throughout the final years of the study period.

These sharp discontinuities observed in Figure 2 cannot be attributed solely to climatic variability, as no rainfall anomalies of similar magnitude were recorded during the same period.

Instead, they point to a governance-driven response to accelerating land degradation, whereby grazing exclusion and set-aside measures were implemented reactively once degradation became clearly apparent. The contrasted trajectories among stations underscore the territorially differentiated effectiveness of grazing regulation policies.

Overall, Figure 2 demonstrates that grazing management in the studied semi-arid rangelands evolved from a relatively permissive regime toward increasingly restrictive exclusion measures, with markedly different outcomes among stations. The long-term effectiveness of these policies appears to depend less on uniform regulatory frameworks than on locally adapted governance arrangements capable of anticipating degradation processes and ensuring continuity in land management.

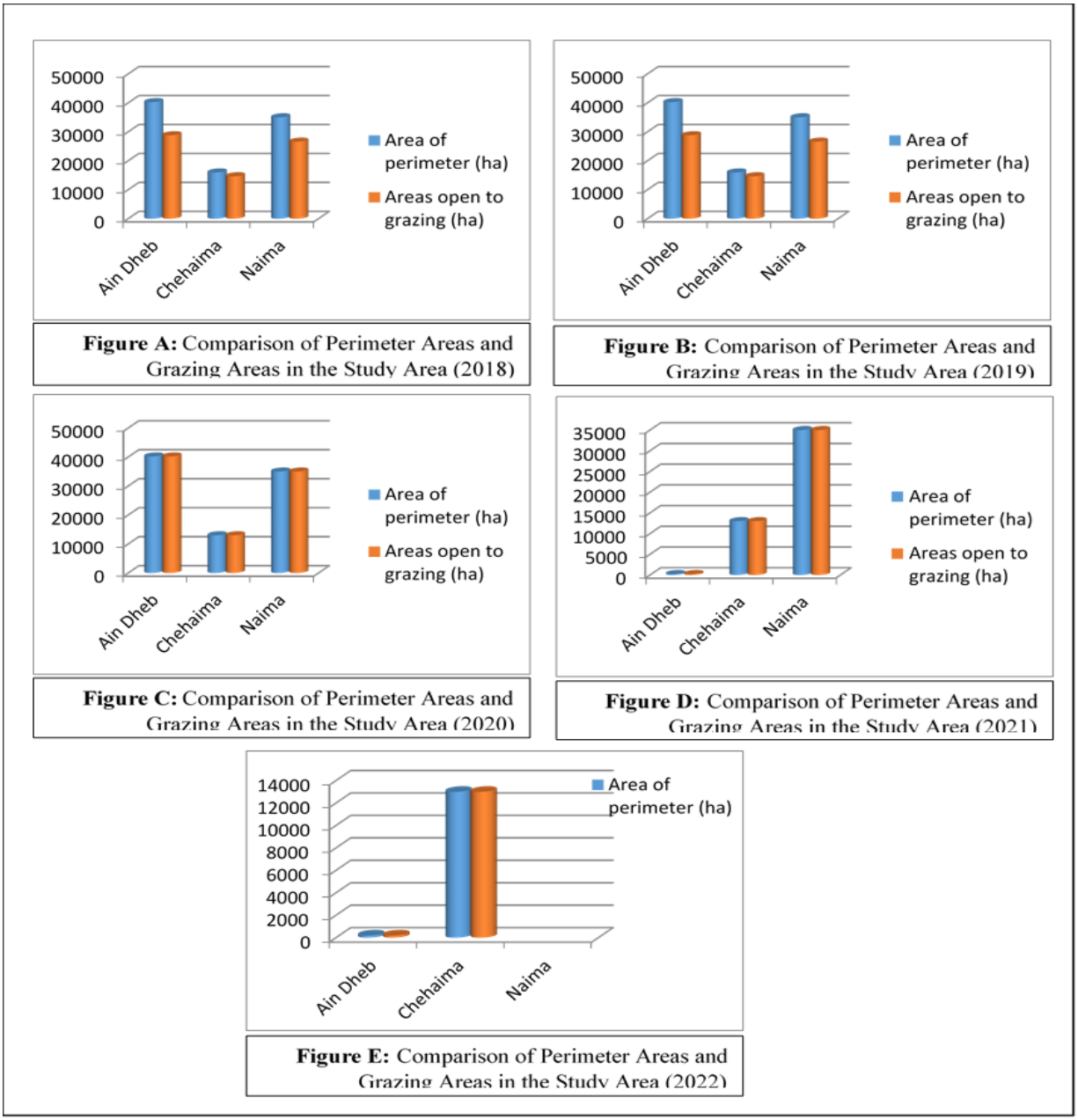


**Figure 2:** Evolution of total area vs. grazing area of study area (2018–2022).
**Source:** Direction of Agricultural Services of Tiaret (DAS, 2018–2022)

### 5. 2 Livestock Numbers and Grazing Pressure

The joint analysis of grazing areas and livestock numbers (sheep and goats) across Ain Dheb, Naima, and Chehaima over the period 2018–2022 (Figure 3), reveals strong spatial and temporal contrasts that reflect both local management practices and broader governance constraints in semi-arid steppe rangelands. Across all stations, livestock densities generally ranged between one and two heads per hectare. While these stocking rates formally comply with administrative thresholds, they frequently exceed the ecological carrying capacity of steppe ecosystems characterized by low and highly variable primary productivity.

In 2018, Figure 3.A reveals a baseline situation marked by high grazing pressure across all study areas. Grazing surfaces were relatively extensive; however, livestock numbers were also high, resulting in stocking rates generally between 1 and 2 heads per hectare. The pressure was particularly pronounced in Chehaima and Naima, where local densities reached the upper limit of this range, indicating intensive use of rangelands. In Ain Dheb, large grazing areas combined with substantial herd sizes maintained significant pressure on steppe vegetation. Overall, 2018 reflects a permissive grazing regime that exceeded the ecological carrying capacity of semi-arid steppes and helps explain the low vegetation performance observed during the same year

As shown in Figure 3.B, grazing pressure peaked during the early phase of the study, particularly in 2019. In Ain Dheb, approximately 40,200 ha were open to grazing, supporting about 80,200 heads. Stocking rates varied spatially within the municipality, reaching one head per hectare in Reyacha El Hamra and two heads per hectare in Megcem Elhalais. During the same year, Chehaima exhibited the highest overall grazing pressure, with nearly 43,000 ha available for grazing and about 86,000 heads, corresponding to two heads per hectare in Poste Hafsa 01 and Si Ziane. Naima also showed high grazing intensity, with 35,000 ha and roughly 70,000 heads, resulting in two heads per hectare in the Mekimen area.

The subsequent period illustrates divergent regulatory trajectories among the three municipalities (Figure 3.C). In 2020, Ain Dheb maintained a large authorized grazing area (around 40,400 ha) while livestock numbers declined to approximately 40,200 heads, indicating partial adjustment between herd size and available grazing space, notably in Megcem Elhalais and Reyacha El Hamra. In contrast, Chehaima experienced a sharp contraction of authorized grazing surfaces, dropping to about 12,000–13,000 ha, while maintaining high stocking densities of two heads per hectare in Si Ziane. Naima, by comparison, showed relative stability in both grazing area (35,000 ha) and livestock numbers (35,000–70,000 heads), maintaining stocking rates of one to two heads per hectare in Mekimen.

A major rupture is evident in Ain Dheb during 2021–2022 (Figure 3. D.E). Authorized grazing areas collapsed to approximately 254 ha in 2021 and further to about 200 ha in 2022, accompanied by a corresponding reduction in livestock numbers to around 508 heads in 2021 and 200 heads in 2022. Despite this drastic contraction, local stocking densities remained high, reaching two heads per hectare in El Alibait in 2021 and one head per hectare in Reyacha El Hamra in 2022. Conversely, Chehaima maintained relatively stable grazing surfaces of about 13,000 ha with approximately 26,000 heads, sustaining two heads per hectare in Si Ziane, thereby becoming the most intensively grazed municipality in 2022. Naima also maintained high grazing pressure, with 35,000 ha and around 70,000 heads, corresponding to two heads per hectare. Overall, Figure 3 clearly demonstrates that grazing governance in the study area primarily regulates access to space rather than herd size. As a result, grazing pressure is displaced and concentrated within specific regions and perimeters, rather than structurally reduced at the landscape scale. The Ain Dheb case illustrates that a combined reduction of grazing area and livestock numbers is possible, but remains exceptional.

At the regional level, the persistence of high stocking densities, often sustained by feed subsidies, reveals a structural incoherence between rangeland conservation objectives and livestock development strategies. This mismatch confines set-aside policies to a reactive and compensatory role, limiting their capacity to function as preventive tools that promote adaptive stocking and long-term steppe ecosystem resilience.

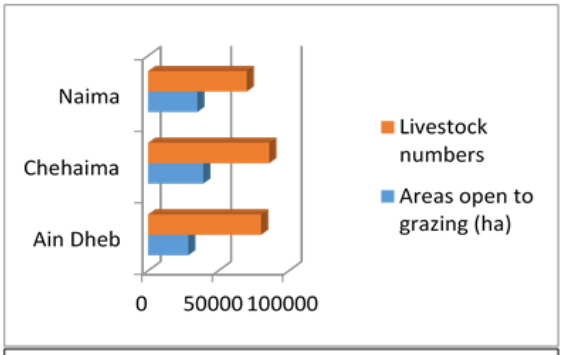


**Figure A:** Comparison between Grazing Areas and Livestock Numbers in the Study Area (2018)

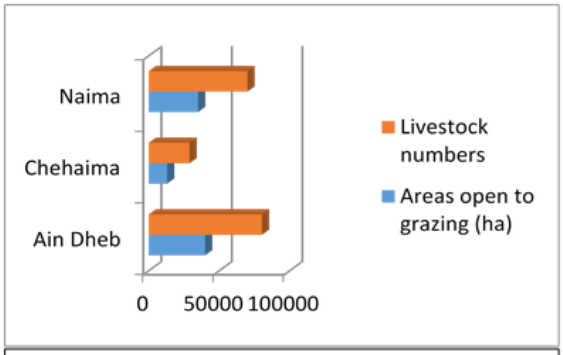


**Figure B:** Comparison between Grazing Areas and Livestock Numbers in the Study Area (2019)

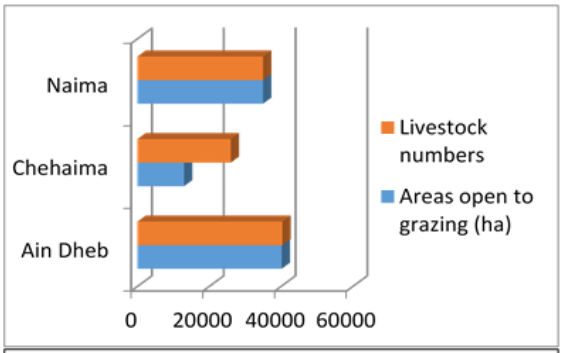


**Figure C:** Comparison between Grazing Areas and Livestock Numbers in the Study Area (2020)

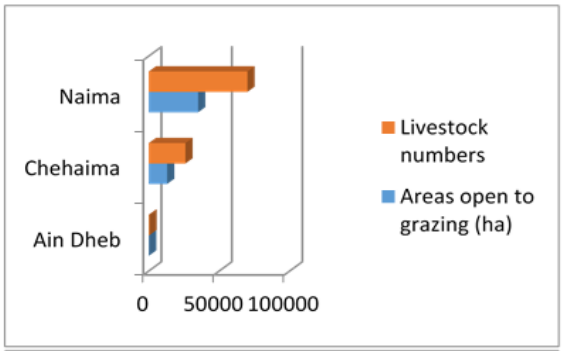


**Figure D:** Comparison between Grazing Areas and Livestock Numbers in the Study Area (2021)

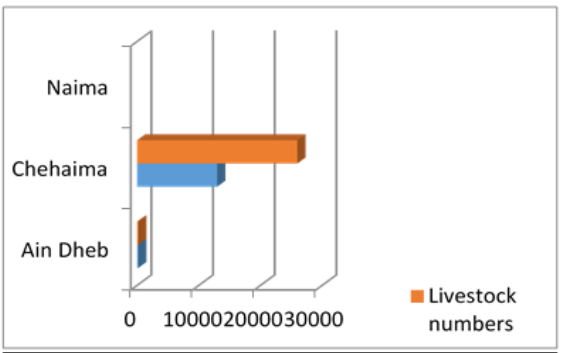


**Figure E:** Comparison between Grazing Areas and Livestock Numbers in the Study Area (2022)

**Figure 3:** Relationship between livestock density (heads/ha) and grazing pressure of study area (2018-2022).

**Source:** Direction of Agricultural Services of Tiaret (DAS, 2018–2022)

### 5.3 Vegetation Cover and Species Dynamics

As shown in Figure 4, the spatio-temporal evolution of vegetation cover derived from NDVI analysis between 2018 and 2022 reflects a strong interaction between ecological processes and grazing governance in the studied steppe rangelands. Across all stations, vegetation cover

generally ranged between 50% and 80%, with consistently higher and more stable values within set-aside perimeters compared to open rangelands.

Figure 4.A indicates that in 2018, NDVI values were relatively low (approximately −0.11 to +0.52), and vegetated areas covered a limited surface, reflecting a landscape dominated by bare soil and sparsely vegetated patches. This situation corresponds to a phase of sustained grazing pressure and insufficient recovery periods, during which plant communities - particularly palatable perennial species such as *Stipa tenaci*ssima - were unable to complete their biological cycles. The dominance of stress-tolerant species and the fragmented vegetation pattern visible in the same figure are characteristic of advanced rangeland degradation.

A marked improvement is visible in Figure 4.B in 2020, when NDVI values increased (up to approximately +0.62) and the surface occupied by vegetated pixels expanded substantially. This phase coincides with the reinforcement of grazing exclusion and the expansion of set-aside perimeters, especially in Ain Dheb and Naima. The spatial coherence of higher NDVI values within protected areas shown in Figure 4.B provides clear evidence of the ecological responsiveness of steppe vegetation to governance interventions. Reduced grazing disturbance allowed annual and perennial species to regenerate, leading to improved ground cover, increased photosynthetic activity, and partial restoration of ecosystem functionality.

However, Figure 4.B also reveals that vegetation recovery remained qualitatively limited. While dominant steppe species such as *Lygeum spartum*, *Plantago albicans*, and *Artemisia herba-alba* became more stable within set-aside areas, the weak or discontinuous presence of Stipa tenacissima indicates that recovery primarily reflects short-term stabilization rather than full structural restoration of steppe ecosystems. This highlights the ecological inertia of degraded steppes and the need for extended protection periods.

In 2022, Figure 4.C shows locally high NDVI values but a clear reduction and fragmentation of vegetated surfaces. This apparent contradiction suggests that vegetation recovery was spatially concentrated within well-protected nuclei, while other areas experienced renewed degradation. This pattern reflects the combined influence of climatic constraints (irregular rainfall and drought episodes) and governance discontinuities, including partial reopening of grazing areas and uneven enforcement of set-aside regulations across municipalities.

Overall, Figure 4 demonstrates that set-aside measures are effective in enhancing vegetation vigor, stabilizing ground cover, and increasing ecosystem resilience in the short to medium term. Nevertheless, the reversibility of gains observed in the final year underscores that ecological recovery in semi-arid steppes is highly dependent on governance continuity, adaptive grazing management, and alignment between livestock pressure and ecological carrying capacity. Without long-term, locally adapted, and participatory governance frameworks, vegetation recovery remains.

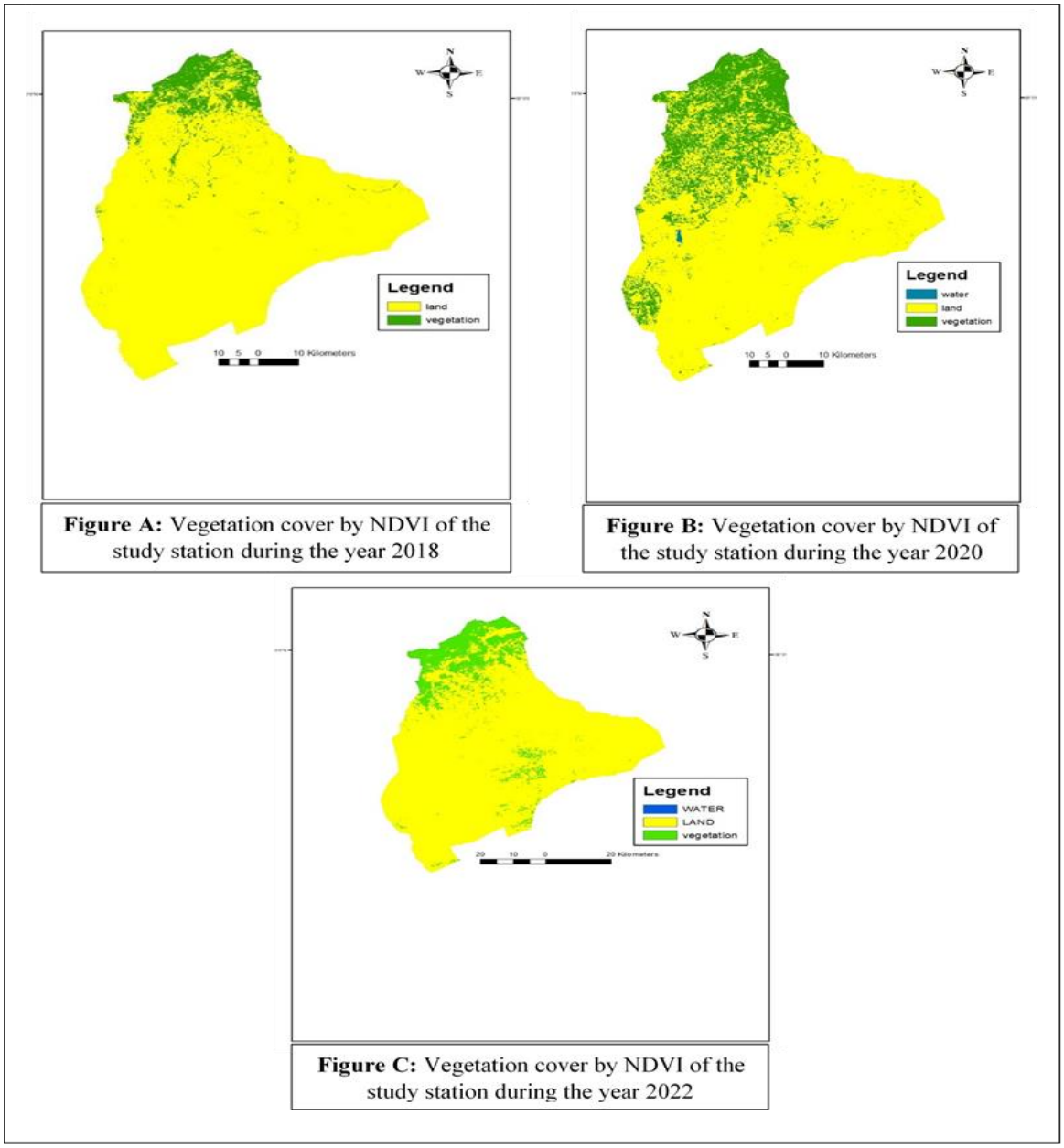


**Figure A:** Vegetation cover by NDVI of the study station during the year 2018

**Figure B:** Vegetation cover by NDVI of the study station during the year 2020

**Figure C:** Vegetation cover by NDVI of the study station during the year 2022

**Figure 04:** Spatiotemporal variation of vegetation cover (NDVI) in the Ain Dheb, Chehaima, and Naima regions between 2018 and 2022.
**Source:** Sentinel-2 imagery,2023

**Table 1.** Summary of administrative, ecological and pastoral information used for the spatio-temporal analysis of rangeland governance and management in the study area (2018–2022).

| Year | Commune | Region | Type | Season | Forage productivity (UF/ha) | Perimeter productivity (UF) | Vegetation cover (%) | Area of perimeter (ha) | Areas open to grazing (ha) | Livestock numbers |
|---|---|---|---|---|---|---|---|---|---|---|
| 2018 | Ain Dheb | Megcem El Halais | SA | Spring | 200 | 8000000 | 65% | 40000 | 28350 | 80000 |
| | | Reyacha el hamra | CP | Spring | 200 | 40000 | 80% | 200 | 200 | 200 |
| | Chehaima | Si Ziane | SA | Spring | 200 | 2600000 | 65% | 13000 | 9150 | 26000 |
| | | Hafsa 01 | SA | Autumn | 200 | 6000000 | 65% | 30000 | 30000 | 60000 |
| | Naima | Mekimen | SA | Spring | 200 | 7000000 | 65% | 35000 | 19650 | 70000 |
| 2019 | Ain Dheb | Megcem El Halais | SA | Spring | 200 | 8000000 | 60% | 40000 | 28550 | 80000 |
| | | EL Alibait | CP | Autumn | 200 | 50800 | 65% | 254 | 254 | 254 |
| | Chehaima | Dhaya Khadra | CP | Autumn | 200 | 587400 | 65% | 2937 | 2937 | 2937 |
| | | Si Ziane | SA | Spring | 200 | 2600000 | 70% | 13000 | 11700 | 26000 |
| | Naima | Mekimen | SA | Spring | 200 | 70000 | 65% | 35000 | 26600 | 70000 |
| 2020 | Ain Dheb | Megcem El Halais | SA | Spring | 200 | 8000000 | 70% | 40000 | 40000 | 40000 |
| | | Reyacha el hamra | CP | Spring | 200 | 40000 | 70% | 200 | 200 | 400 |
| | Chehaima | Si Ziane | CP | Spring | 200 | 2600000 | 65% | 13000 | 13000 | 26000 |
| | Naima | Mekimen | CP | Spring | 200 | 7000000 | 60% | 35000 | 35000 | 35000 |
| 2021 | Ain Dheb | EL Alibait | CP | Winter | 200 | 50800 | 65% | 254 | 254 | 508 |
| | Chehaima | Si Ziane | SA | Winter | 200 | 2600000 | 70% | 13000 | 13000 | 26000 |
| | Naima | Mekimen | SA | Winter | 200 | 7000000 | 70% | 35000 | 35000 | 70000 |
| 2022 | Ain Dheb | Reyacha el hamra | CP | Spring | 200 | 40000 | 50% | 200 | 200 | 200 |
| | Chehaima | Si Ziane | SA | Spring | 200 | 2600000 | 80% | 13000 | 13000 | 26000 |

**Source:** Direction of Agricultural Services of Tiaret (DAS, 2022)

Between 2018 and 2022, the steppe rangelands of Ain Dheb, Chehaima, and Naima showed a relatively stable theoretical forage productivity (200 UF/ha); however, the actual ecological condition varied markedly among sites and years. Variations in total forage production were mainly driven by differences in perimeter size rather than improvements in vegetation condition. Vegetation cover (NDVI) exhibited clear interannual fluctuations, with higher values observed in some years and locations, indicating temporary regeneration, while significant declines, particularly in Naima in 2021, reflected rangeland degradation.

Livestock pressure was highly heterogeneous and, in several cases, exceeded the grazing capacity of the rangelands, leading to overgrazing and reduced vegetation cover. Areas under protective management (mise en défens) generally maintained better vegetation conditions compared to open or poorly controlled pastures, although their effectiveness depended on enforcement and grazing regulation. Overall, the mismatch between forage potential and actual grazing pressure highlights the dominant role of anthropogenic stress in driving steppe degradation and emphasizes the need for adaptive grazing management to ensure long-term rangeland sustainability.

**6. General Discussion**

The present study highlights the central role of set-asides as a governance-based instrument for mitigating land degradation and promoting vegetation recovery in semi-arid steppe ecosystems. NDVI-based analyses provide clear evidence of improved vegetation cover and enhanced ecosystem stability within protected perimeters, confirming that grazing exclusion can rapidly trigger positive ecological responses. These results are consistent with previous studies conducted in Algerian steppe regions, which have demonstrated the strong sensitivity of vegetation dynamics to grazing pressure and land-use regulation when analyzed through remote sensing and GIS-based approaches (Azzaoui et al., 2018 ; Bouacha, 2019 ; Zaidi et al., 2025 ; Pettorelli et al., 2005). Moreover, the observed patterns of species recovery and floristic diversity align with local floristic surveys highlighting the vulnerability of key steppe species under intensive grazing (Benkhettou et al., 2015 ; Negadi et al., 2014).".

The rapid increase in NDVI values following grazing exclusion reflects the high sensitivity of steppe vegetation to management interventions. This sensitivity is typical of arid and semi-arid rangelands, where vegetation dynamics are strongly constrained by disturbance regimes rather than solely by climatic variability (Ellis & Swift, 1988 ; Le Houérou, 2001). However, while the ecological effectiveness of set-asides is clearly demonstrated at the local scale, the results also reveal significant spatial disparities in vegetation recovery among Ain Dheb, Naima, and Chehaima, underscoring the decisive role of governance arrangements.

The spatio-temporal NDVI variations observed between 2018 and 2022 corroborate previous results on steppe vegetation dynamics, where grazing exclusion favors temporary regeneration and partial ecosystem stabilization (Bouacha, 2019 ; Zaidi et al., 2025).

Differences observed between municipalities highlight that the success of set-asides is not determined only by biophysical conditions, but is strongly conditioned by local governance capacity, continuity of enforcement, and stakeholder compliance. Ain Dheb, where grazing exclusion was applied more strictly and consistently, exhibited clearer ecological gains, whereas Chehaima and Naima showed more variable outcomes. This territorially differentiated effectiveness is widely reported in land degradation governance studies, which emphasize that conservation measures lacking strong institutional support and social legitimacy often produce short-lived or spatially uneven ecological benefits (Hammouda & al., 2019 ; FAO, 2019 ; UNCCD, 2021).

Despite the positive vegetation response within protected areas, the overall sustainability of these gains remains fragile. Livestock densities across the study area, frequently exceeded the ecological carrying capacity of steppe rangelands, even when they formally complied with

administrative thresholds. This mismatch reflects a structural decoupling between herd size and local forage availability, a phenomenon widely documented in arid pastoral systems (Scholes & Archer, 2015 ; Teague et *al*., 2011). The persistence of high livestock numbers during periods of restricted grazing access indicates that current governance mechanisms primarily regulate space rather than herd size.

As a result, grazing pressure is not structurally reduced but rather displaced and concentrated on non-protected areas, limiting the long-term ecological effectiveness of set-asides. Feed subsidy policies further exacerbate this dynamic by buffering livestock production against local ecological constraints, thereby weakening traditional feedback mechanisms between vegetation availability and stocking rates (Behnke & Scoones, 1993 ; Le Houerou, 2001). In this context, set-asides tend to function as reactive or compensatory tools activated once degradation becomes visible, rather than as preventive instruments embedded within an adaptive rangeland management framework.

The differential recovery among communes reflects both ecological inertia and the influence of local governance. Similar patterns of vegetation heterogeneity under varying grazing pressures have been documented in other steppe areas of Algeria (Benkhettou et al., 2015), emphasizing the role of site-specific management in shaping ecological outcomes.

Species composition within set-aside perimeters showed a tendency to favor stress-tolerant and perennial species, in agreement with floristic surveys of the Massif du Nador and El Bayadh regions (Benkhettou et al., 2015; Negadi et al., 2014).

From a coupled socio-ecological perspective, these findings reveal a clear policy incoherence between rangeland conservation objectives and livestock development strategies. While set-asides demonstrate strong short-term ecological potential, their transformative capacity remains limited in the absence of integrated governance approaches that simultaneously address spatial access, herd regulation, and socio-economic drivers of pastoral pressure. Long-term steppe restoration therefore requires a shift toward adaptive governance models that reconcile ecological carrying capacity with pastoral livelihoods through flexible stocking strategies, participatory management, and policy alignment across sectors (FAO, 2019 ; UNCCD, 2021).

## 7. Conclusion and Perspectives

This study provides a comprehensive and empirically grounded assessment of set-asides as a state-led land governance instrument for restoring degraded steppe ecosystems in Algeria, using the Tiaret region as a representative case of study. By combining remote sensing analysis (NDVI) with spatially explicit grazing and livestock data, the results clearly demonstrate that set-asides contribute to reducing grazing pressure, enhancing vegetation cover, and improving the ecological stability of rangelands, when grazing exclusion is strictly and consistently enforced. These results confirm that steppe vegetation remains highly responsive to management interventions, even in semi-arid contexts characterized by strong climatic variability.

Beyond their ecological effectiveness, set-asides emerge as fundamentally political and institutional instruments. Their implementation reflects a sustained public policy commitment by the Algerian state to combating land degradation and desertification, as well as to regulating access to common-pool rangeland resources. The continuity of interventions between 2018 and 2022, the mobilization of public institutions, and the territorial differentiation of regulatory measures, together, they illustrate a concrete translation of political will into land governance practices. In this sense, set-asides represent not only ecological restoration tools but also mechanisms through which state authority and environmental regulation are spatially enacted.

However, the study also reveals important limitations that constrain the long-term sustainability of this strategy. Strong spatial variability among municipalities highlights the decisive role of local governance capacity, enforcement continuity, and social legitimacy in shaping ecological

outcomes. More critically, the persistence of high livestock numbers despite access restrictions, exposes a structural mismatch between rangeland conservation objectives and livestock development policies. In practice, set-asides tend to regulate space more effectively than grazing pressure, leading to the spatial displacement and concentration of livestock rather than to a structural reduction of stocking rates. As a result, ecological gains remain partial, fragile, and potentially reversible once an exclusion measures are relaxed.

From a governance perspective, these findings underline the limits of command-and-control approaches when applied in isolation. While exclusion-based measures can generate rapid short-term ecological benefits, their long-term effectiveness depends on their integration into more adaptive and participatory governance frameworks. Aligning livestock numbers with the ecological carrying capacity of steppe rangelands, improving institutional coordination across sectors, and ensuring the meaningful involvement of pastoral communities, in decision-making processes are an essential conditions for durable restoration. Without such integration, set-asides risk remaining reactive and compensatory tools rather than preventive instruments capable of transforming degradation trajectories.

Looking ahead, several perspectives emerge for both research and policy. Future studies should assess the socio-economic impacts of set-asides on pastoral households and evaluate the feasibility of co-management arrangements that combine state leadership with local stewardship. The institutionalization of remote sensing and GIS-based monitoring systems, offers strong potential for adaptive governance, continuous evaluation, and evidence-based policy adjustment. Finally, explicitly integrating set-asides into national land restoration, climate adaptation, and sustainable livestock strategies would strengthen their role as long-term instruments for enhancing the resilience of both steppe ecosystems and pastoral livelihoods in Algeria.

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