Research Article

Use of Fenced Pastoral Areas in Algerian Steppe Sheep Breeding: A Case Study of Tiaret Region

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Abstract | This study investigates the use of fenced pastoral areas for sheep breeding in the Algerian steppe, focusing on the Tiaret region. Random interviews were conducted with 25 and 38 tenant breeders in the two main fenced areas of M'Kimen and Saouas, respectively. The survey focused on breeder origins, flock management strategies, and rangeland exploitation modalities. Results reveal that while fenced areas serve as vital fodder sources for tenant breeders, they remain susceptible to significant overgrazing, with average stocking rates exceeding recommended carrying capacity by 60.4% (M'kimen) and 58.4% (Saouas). This persistent overstocking reflects an economic calculus prioritizing short-term forage maximization despite long-term ecological costs. The study underscores the critical need for improved management practices, particularly regulated carrying capacity enforcement and real-time monitoring mechanisms to ensure rangeland sustainability and long-term productivity. These findings contribute essential insights for developing evidence-based policies for sustainable pastoral management in arid steppe regions.

Keywords | Sheep, Steppe, Rangeland, Overgrazing, Carrying capacity, Fenced pastoral, Sustainability

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INTRODUCTION

The Algerian steppe covers an extensive region spanning approximately 20 million ha, with rangelands accounting for 13 million ha. These areas have historically supported extensive livestock grazing, primarily of sheep, goats, and camels, alongside intermittent rainfed cereal production (Aïdoud *et al.*, 2006). In recent decades, however, the natural steppe ecosystems have undergone substantial degradation, marked by a notable reduction in both their spatial extent and pastoral carrying capacity (Abbas, 2004). Research indicates a sharp decline in rangeland productivity over the past four decades, with fodder unit (UF) yields dropping below 50 UF/ha across much of the steppe (Aïdoud *et al.*, 2006). Concurrently, the Algerian sheep population, which is predominantly concentrated in the steppe zone, has expanded intensely, rising from 5 million head in 1962 to over 30 million by 2019 (MADR, 2020). Approximately 62% of this population, equating to 18.6 million head, remains within the steppe region. This escalating livestock density exerts persistent pressure on the already fragile rangelands, exacerbating their ongoing degradation.

In response to ongoing ecosystem degradation, the High Commission for Steppe Development (HCDS), a specialized public institution, has overseen initiatives aimed at integrated pastoral development. Among its strategies,

fenced pastoral has been employed as a passive restoration technique (Amghar *et al*., 2016). Recent HCDS reports indicate that approximately 3 million hectares have been rehabilitated through fenced pastoral and 300,000 hectares through pastoral plantations (Nedjraoui and Bédrani, 2008). These interventions aim to reconcile livestock production with rangeland preservation.

Studies confirm fenced pastoral's biophysical benefits, including enhanced vegetation diversity, and soil conditions in Algerian/Tunisian steppes (Amghar *et al*., 2016; Kouba *et al*., 2021; Doghbage *et al*., 2024). Moroccan analogs show reduced sand dynamics and erosion, though gains fade without sustained controls (El-Badaouy *et al*., 2023). Literature strengths in restoration metrics are offset by gaps in post-release dynamics, breeder agency, novel mobilities (e.g., Djelfa transhumance rerouting; Gaci *et al*., 2021). Moreover, declines in fodder productivity receive limited contextualization relative to climate variability, and regional syntheses across the Maghreb overlook enforcement challenges intertwined with economic incentives (Ferchichi and Abdelkebir, 2003; Chaieb, 1989).

Fencing has been promoted as a restoration tool and sustainable management strategy. However, critical questions remain: (1) How effectively do breeders integrate fenced areas into their management systems? (2) Do current practices promote rangeland regeneration and preservation, or do economic pressures drive unsustainable exploitation? (3) What mechanisms can ensure that fenced areas achieve their intended ecological and economic objectives?

This underscores the gap: Biophysical gains mask socio-ecological barriers in mobility integration, overgrazing persistence, and policy levers amid climate stress. Unlike vegetation audits, this study addresses these gaps by examining the integration of fenced areas as feed resources within flock management practices in Tiaret region, with specific focus on tenant characteristics, grazing behaviors, stocking rates, and the mechanisms driving overgrazing despite awareness of carrying capacity constraints. The findings aim to enhance management strategies for fenced lands and inform development programs for sustainable sheep breeding in the steppe.

MATERIALS AND METHODS

Research methodology

This study is conducted as part of a research project led by the Scientific and Technical Research Center for Arid Regions (CRSTRA). The main objective of this project is to develop a decision-support tool for the sustainable management of resources in the arid steppe. The adopted methodology involves conducting interviews during a single visit to breeders renting fenced pastoral areas. These interviews aim to gather information on access practices and the use of fenced pastoral rangelands. This interview approach allows for the rapid and realistic collection of data on livestock systems (Lhoste, 2001).

Study area

The Tiaret region, located in the northwest of Algeria (Figure 1), has been selected for this study due to its agro-pastoral strengths, stemming from its geographical and climatic diversity. Tiaret can be divided into three distinct agricultural and pastoral zones: (i) High Plateaus Zone (northern part), characterized by a mix of crop and cattle livestock production; (ii) Plains Zone (central part), primarily used for cereal cultivation; and (iii) Steppe Zone (southern region), primarily dedicated to sheep and goat breeding under arid conditions. The steppic zones of Tiaret benefit from favorable pedoclimatic conditions, particularly a rainfall regime conducive to vegetation regeneration. Tiaret has the largest area of fenced pastoral in Algeria, totaling 245,522 ha (Habib, 2012). For the purposes of this study, two fenced pastoral areas were selected: M'Kimen and Saouas (Figure 2), due to their significance as fodder resources and their potential for biodiversity conservation.

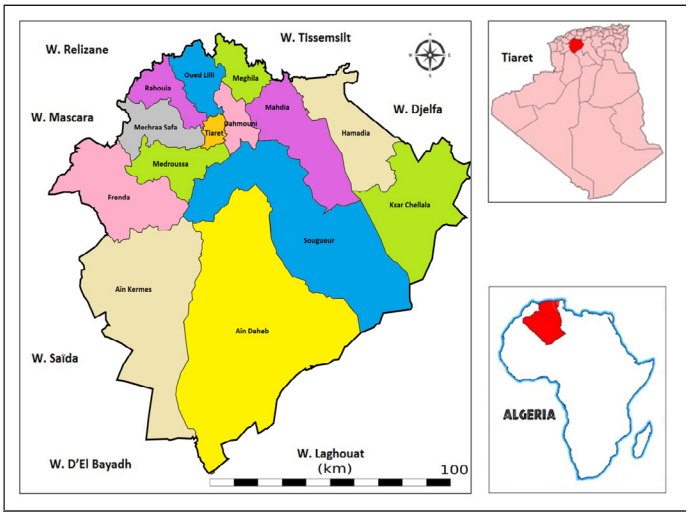

Figure 1: Location of the Tiaret Region.
Source: HCDS, 2019 (adapted).

The M'Kimen pastoral fencing is situated in the southeast of the Tiaret wilaya, within the Naïma municipality. Spanning 35,000 ha, it is one of the largest fenced pastoral projects in the region, providing a substantial pastoral reserve for breeders during rental periods. The Saouas pastoral fencing, located in the southwest of the Tiaret wilaya within the Sidi Abderrahmane municipality, is bordered by Chott El Chergui on three sides (east, south, and west). Covering an area of 10,000 ha, it likewise functions as a significant pastoral reserve.

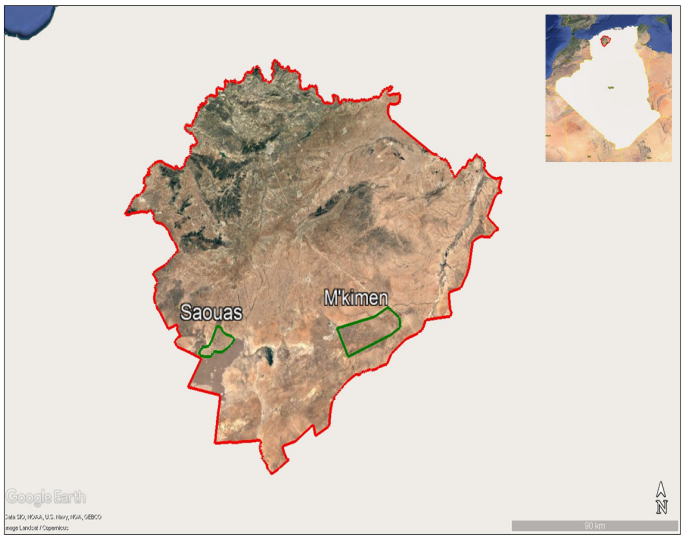

Figure 2: Location of the study's pastoral fencing areas.
Source: Image adapted from Google Earth (2023).

Data collection and processing

Interviews were conducted with tenant breeders to obtain information on the use of the fenced pastoral areas, specifically regarding: the origin of the tenant breeders and their motivations for renting; the terms of the rental agreements; the nature and organization of the managed flocks; and the feed management of the flocks during the rental period.

A random sample of 25 breeders (26% sample) was selected from a total of 96 tenant breeders of the M'Kimen pastoral fencing during the spring rental season of 2017. For the Saouas pastoral fencing, a sample of 38 breeders (40% sample) was drawn from the same total of 96 tenants during the spring rental season of 2018. The discrepancy in timing is attributed to administrative constraints: legislation mandates a minimum registration rate of tenants set at 70% of the total area before rental openings are permitted. Rather than a limitation, this temporal difference was integrated into the analysis to examine breeders' choice, frequency, and decision to rent fenced rangelands. Surveys in both areas were conducted during the spring rental period, a critical phase for grazing decisions, and the analysis therefore focuses on structural determinants of rental and grazing practices.

The official procedure for renting a fenced pastoral area comprises the following administrative steps:

1. Assessment of the fenced pastoral by the HCDS technical services to determine the possibility of opening it for rental and to estimate the carrying capacity.
2. Proposal to the wali (head of the department) to rent the fencing area, established by the local authority in collaboration with the HCDS.
3. A decree is issued by the wali authorizing the opening of the land for rental, specifying the total area, the grazing period (generally 2 months), the rental fees (1,000 DA/ha ≈ 8.5 $/ha at the 2017–2018 exchange rate of 1$ = 117 DA), and the permissible carrying capacity (head/ha).
4. Registration and payment of rental fees by interested breeders. The legal requirement states that at least 70% of the total area must be registered before the fencing can be opened.
5. Division of the fenced pastoral into plots of 100 ha, with marking done by sandbags by a hired surveyor.
6. Admission of flocks into the rented plots, based on the area rented by each breeder.
7. Removal of flocks at the end of the rental period.

All breeders interviewed at both sites confirmed their agreement with the adequacy and transparency of this procedure and considered the rental price affordable.

Given the right-skewed distributions of stocking rates and rented areas (confirmed by Shapiro-Wilk tests), median and interquartile ranges (IQR: Q1–Q3) are reported as the primary measures of central tendency throughout the results section. Mean ± standard deviation (SD) values are provided in parentheses for transparency where relevant.

Key variables

Carrying capacity

According to Le Houérou (1969), rangeland carrying capacity (CC) is defined as the maximum number of livestock units that a rangeland can sustainably support over a given period without causing long-term degradation of vegetation, soil, or ecosystem functioning. It represents a dynamic balance between forage production, animal requirements, and acceptable utilization rates under specific climatic conditions. Le Houérou expresses carrying capacity as a function of usable forage biomass and animal intake:

$$CC = \frac{P \times U}{R}$$

Where: CC= carrying capacity (Livestock Units per hectare or ha per LU), P= annual forage production (kg dry matter·ha^{-1}·year^{-1}), U = allowable utilization rate of biomass (dimensionless, generally between 0.30 and 0.40 in steppes), R= annual forage requirement per livestock unit (kg dry matter·LU^{-1}·year^{-1}).

Overgrazing coefficient

The overgrazing coefficient measures the excess livestock pressure on rangeland relative to its forage production capacity, indicating a critical level of ecological stress. It is commonly calculated using the formula (Le Houérou, 1969):

$$S = \left(1 - \frac{Ce}{Cr}\right) \times 100$$

C_e: Equilibrium stocking rate; C_r: Actual stocking rate (existing livestock), thereby reflecting the degree of environmental degradation.

Interpretation

Accordingly, a coefficient of S% indicates that the actual stocking rate (Cr) is S% higher than the recommended equilibrium carrying capacity (Ce). For example, S= 60% means breeders are stocking at a rate 60% above what the rangeland can sustainably support. A positive value (Cr > Ce) confirms overgrazing; the higher the coefficient, the greater the ecological stress. A high coefficient indicates rapid degradation of vegetation cover and excessive pressure on ecosystems, particularly in steppe environments.

Livestock unit (LU) standardization

All livestock counts were standardized to livestock units (LU) using internationally accepted coefficients: sheep = 1 LU; goats = 0.8 LU; cattle = 6 LU (FAO, 2011). This standardization eliminates bias introduced by different animal sizes. It should be noted that these are standard static coefficients based on mean adult body weight and do not account for intra-class metabolic variability; for example, the differential metabolic demands of ewes in lactation versus dry ewes, or of rapidly growing lambs versus adult animals. This is a recognized methodological limitation and is discussed further in the discussion section.

Statistical analysis

Interview data analysis combined descriptive and inferential statistics. One-way ANOVA with Fisher's LSD post-hoc test compared carrying capacity across exploitation modalities per site. Pearson's r examined the relationship between rented area and flock size. The Mann-Whitney U test was used to compare overgrazing coefficients between sites. Shapiro-Wilk and Levene's tests verified normality and variance homogeneity, data transformations were applied as needed. Sample independence was confirmed through study design. All analyses were conducted in XLstat at $\alpha = 0.05$.

RESULTS

The results are presented following a logical progression addressing four questions: (i) Who uses the fenced pastoral areas and why? (ii) How are the fenced pastoral areas accessed and utilized? (iii) What is the outcome of this utilization? (iv) What characterizes the flocks exerting this pressure?

Who uses the fenced pastoral areas and why?

Identification and origins of tenant breeders

Identifying the origins of tenant breeders, the modalities of the rental agreements, and the nature of the flocks being managed are key to understanding the usage conditions of the fencing areas

For the M'Kimen pastoral fencing, the tenants are predominantly from the wilaya of Djelfa (60% of respondents), followed by those from Tiaret (28%) and Laghouat (12%). In terms of the global rented space, tenants from Djelfa, Tiaret, and Laghouat have rented 73.5%, 19.7%, and 6.8% of the total rented land, respectively (Table 1).

Table 1: Origins of the tenant breeders surveyed in the M'Kimen pastoral fencing.

Origin Wilaya	Number of Breeders	Breeders (%)	Rented area (ha)	Area (%)
Djelfa	15	60%	8 600	73.5%
Tiaret	7	28%	2 300	19.7%
Laghouat	3	12%	800	6.8%
Total	25	100 %	11 700	100%

The presence of one respondent who is not an official tenant but utilizes land on the periphery of the fenced pastoral; following the early departure of some tenants, represents a subtle source of rangeland degradation. Similar practices have been reported by Bencherif and Slimani (2021) in the neighboring region of El-Bayadh.

For the Saouas pastoral fencing, the tenants are primarily from the surrounding areas within the same Tiaret wilaya (94.7% of the sample), with the remaining two breeders from neighboring wilayas (Saïda and El-Bayadh). Tiaret's tenant breeders account for 92% of the rented fencing area (Table 2).

Table 2: Origins of the tenant breeders surveyed in the Saouas Pastoral Fencing.

Origin Wilaya	Number of breeders	Breeders (%)	Rented area (ha)	Area (%)
Tiaret	36	94.7%	3 645	92%
El Bayadh	1	2.6%	100	3%
Saida	1	2.6%	200	5%
Total	38	100%	3 945	100%

Rental frequency and motivations

Fodder scarcity during certain periods compels breeders to rent fenced pastoral areas in order to reduce their feed costs. There is a clear trend toward incorporating these areas as recurring fodder resources (Table 3): 71% of M'Kimen breeders (50% same site annually + 21% another site annually) and 82% of Saouas breeders (77% same site annually + 5% another site annually) rent each year, indicating behavioral stability and the institutionalization of fenced pastoral areas as a routine management

tool. Breeders from distant regions (Djelfa, Laghouat) typically conduct preliminary vegetation assessments before committing to rental, while proximal breeders are motivated primarily by accessibility.

Table 3: Rental frequency in the pastoral fencing areas.

Frequency	M'Kimen breeders (%)	Saouas breeders (%)
The same pastoral fencing each year	50%	77%
Each year in a pastoral fencing	21%	5%
Uncertain frequency	21%	5%
The first time	8%	13%
Total	100%	100%

How are the fenced pastoral areas accessed and utilized?

Temporal patterns: Official vs. Actual grazing periods

Although the rental period is defined in advance in the rental decree, discrepancies are observed between the official and actual grazing periods. At M'Kimen, the official spring 2017 period ran from mid-March to mid-May; however, only 42% of tenants respected these dates, while 58% grazed during April and May only. This discrepancy is due to delays in rental fee payments by some breeders, which delay their access to the rangelands. At Saouas, the official spring 2018 period ran from mid-April to mid-June; only 61% of tenants respected these dates, while 39% entered early, having already paid rental fees from the previous season when the fencing was not opened due to the 70% threshold not being met. Thus, some flexibility is observed in access dates, influenced by both tenant and legal factors.

Rented areas and distribution patterns

At M'Kimen (n = 96), rented areas exhibited a median of 200 ha (Q1: 100 ha, Q3: 300 ha; range: 50-2,000 ha), with 75% of tenants occupying 100-300 ha parcels. The fenced pastoral achieved an 82.43% rental rate, exceeding the legal 70% threshold (Figure 3). At Saouas (n = 96), the median rented area was 80 ha (Q1: 50 ha, Q3: 100 ha; range: 20–600 ha), with 75% of tenants occupying 50-100 ha parcels. The rental rate reached 85.90%, likewise surpassing the mandatory threshold (Figure 4).

Exploitation modalities

The Table 4 synthesizes the exploitation modalities observed at both sites. Two fundamental modalities of rangeland use were identified: 'single use' (one breeder per plot) and a collective use pattern. At M'Kimen, the collective modality is termed 'co-sharing' (one official renter with additional informal participants), while at Saouas it is termed 'co-usage' (all participants are official renters).

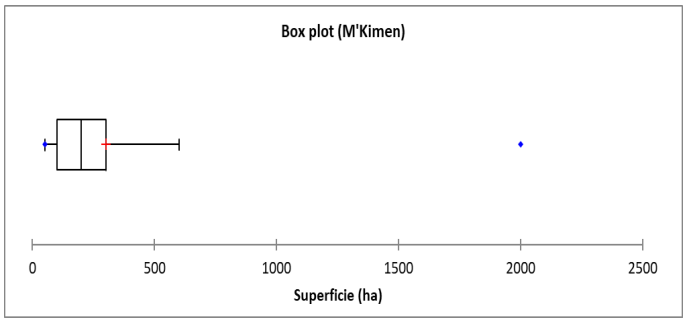

Figure 3: Box Plot of Tenant Breeders in the M'Kimen Pastoral Fencing.

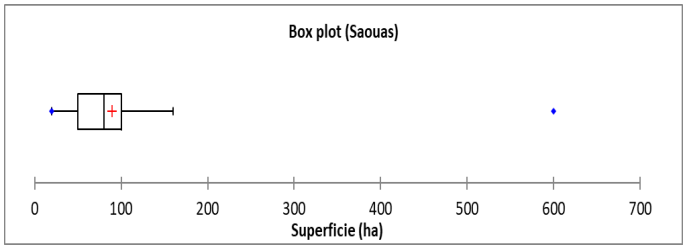

Figure 4: Box Plot of Tenant Breeders in the Saouas Pastoral Fencing.

The non-significant effect of use structure on grazing pressure reflects a shared tendency among breeders to maximize rangeland use under persistent fodder deficit; thus, grazing intensity is primarily driven by resource constraints rather than organizational modality. Qualitative interviews nonetheless reveal behavioral differences: in co-sharing arrangements (M'Kimen), informal participants were less likely to regulate collective flock loads due to lack of tenure rights, whereas in co-usage systems (Saouas), access was more equitable but lacked coordination mechanisms to limit total stocking. Despite these differences, no formal conflicts were reported, and similar supplementation rates across modalities further support the predominance of systemic fodder limitation.

Table 4: Fenced pastoral exploitation modalities.

Modality		Description	M'Kimen (%)	Saouas (%)
Single use		One breeder exclusively utilizes the rented plot.	42%	66%
Collective use	Co-sharing	Multiple breeders (typically 3–10 flocks) collectively use a single rented plot, officially leased by one breeder while the others participate informally.	58%	/
	Co-usage	Multiple breeders (2–7 flocks) jointly utilize a single plot, all as official renters.	/	34%

What is the outcome of this utilization?

Actual stocking rates

In both pastoral fencing areas, the actual stocking rate frequently exceeds the recommended carrying capacity of 2 LU/ha; the technical standard adopted by the HCDS (2010), derived from forage productivity assessments of Algerian steppe rangelands.

At M'Kimen, the median stocking rate was 1.75 LU/ha (Q1: 1.20, Q3: 2.94; mean: 2.38 ± 1.83 LU/ha), with values ranging from 0.91 to 9.00 LU/ha. At Saouas, the median stocking rate was 2.48 LU/ha (Q1: 1.85, Q3: 3.83; mean: 3.08 ± 1.90 LU/ha), with values ranging from 1.14 to 11.73 LU/ha. (Note: the full Saouas range of 1.14–11.73 LU/ha is internally consistent with the reported median of 2.48 LU/ha; these two figures are not in contradiction.) Both sites show upper quartiles (2.94 and 3.83 LU/ha) well above the 2 LU/ha guideline, indicating systematic overstocking during spring rentals.

Effect of exploitation modality on carrying capacity

Descriptive comparison of stocking rates across exploitation modalities showed no notable pattern at either site. One-way ANOVA confirmed the absence of a statistically significant difference: M'Kimen: $F(2,22) = 0.89$, $p = 0.425$, $R^2 = 0.12$; Saouas: $F(2,35) = 0.61$, $p = 0.548$, $R^2 = 0.05$. The null hypothesis of equal means across modalities was therefore retained for both sites, indicating that use structure (single use, co-sharing, or co-usage) does not significantly influence grazing pressure.

A significant positive correlation was found between rented area and flock size at M'Kimen (Pearson's $r = 0.47$, $p = 0.02$, $R^2 = 0.22$), suggesting that larger flocks tended to secure larger parcels. However, with $R^2 = 0.22$, only 22% of the variance in flock size is explained by rented area, leaving 78% unexplained. This unexplained variance likely reflects the fact that flock sizes are primarily determined by pre-existing herd composition and economic strategy rather than by available rental area; breeders tend to bring established flocks to the fencing regardless of plot size, consistent with the economic calculus of maximizing forage extraction. This reinforces the argument that overstocking is systemic rather than area-allocation driven. In contrast, no significant relationship was observed at Saouas ($r = 0.19$, $p = 0.25$), where fixed parcel constraints appear to limit proportional area allocation.

Overgrazing coefficient

The overgrazing coefficient showed a median of 60.4% at M'Kimen (Q1: 47.9%, Q3: 79.1%; range: 18.5-93.6%) and a median of 56.5% at Saouas (Q1: 47.3%, Q3: 71.9%; range: 15.3-90.1%). These values confirm that, on average, actual stocking rates at M'Kimen are 60.4% above the equilibrium carrying capacity, and those at Saouas are 56.5% above; meaning breeders are loading their flocks substantially beyond what the rangeland can sustainably support. The Mann-Whitney U test confirmed no significant inter-site difference ($U = 982$, $p = 0.685$), indicating uniform overgrazing pressure across both sites. This consistent overstocking drove 95.8% of M'Kimen tenants and 92.1% of Saouas tenants to provide concentrate feed supplements during rental periods, suggesting widespread recognition of fodder deficits.

What characterizes the flocks exerting this pressure?

Flock management strategies

In both fenced pastoral areas, the managed flocks are primarily composed of sheep, although a few goats or local cattle are managed alongside the sheep. At M'Kimen, all breeders bring their entire flocks. At Saouas, 60.5% of breeders bring their entire flock, while the remaining 39.5% bring only adult animals, leaving lambs in barns for fattening. This diversity in flock categories is attributed to the greater distance of M'Kimen from many breeders' home locations, which favors full-flock transhumance.

This practice difference is relevant to LU-based stocking comparisons: the 39.5% of Saouas breeders who exclude lambs are bringing flocks with a different metabolic profile (predominantly adult ewes) than full flock breeders. However, despite this partial lamb exclusion, Saouas still records a higher median stocking rate (2.48 vs. 1.75 LU/ha), indicating that other factors; notably smaller parcel sizes relative to flock sizes and the fixed parcel constraint effect ($r = 0.19$, $p = 0.25$); dominate over the compositional effect.

Flock size distribution

At M'Kimen, 50% of breeders own flocks of 201–500 sheep, while 37.5% manage more than 500 head and account for 65.7% of total animal heads at this site. The average flock size at M'Kimen is 543 heads per breeder, reflecting its role as a hub for large-scale transhumant operators (Table 5). At Saouas, 63.2% of tenants own 201–500 sheep (accounting for 66.4% of total animal heads), with only 7.9% exceeding 500 heads. The average flock size at Saouas is 273 heads per breeder (Table 6), consistent with its more locally sourced, smaller-scale patronage.

Animal composition of flocks

Regardless of flock size, sheep flock composition follows a broadly consistent pattern: approximately 63% ewes, 3% rams, and 34% lambs for breeders bringing entire flocks; and approximately 95% ewes and 5% rams for those bringing adult animals only (Figure 5). Goats account for approximately 2.7% of managed flocks. Ten breeders located near Saouas also bring local breed cattle (mean: approximately 3 heads per breeder), further contributing to LU-based stocking pressure in that fencing.

Table 5: Classes of tenants based on the flock introduced to the M'Kimen pastoral fencing.

Classes	No. of breeders	Percentage (%)	Total number of animals	Average size (heads/ breeder)	Percentage (%)
Class I [150 to 200 heads]	3	12.5%	487	162	3.7%
Class II [201-500 heads]	12	50.0%	3 987	332	30.6%
Class III + 501heads	9	37.5%	8 554	950	65.7%
Total	24	100%	13 028	543	100%

Table 6: Classes of tenants based on the flock introduced to the Saouas pastoral fencing.

Classes	No. of breed-ers	Percentage (%)	Total number of animals	Average size (heads/ breeder)	Percentage (%)
Class I [100 to 200 heads]	11	28.9%	1 547	141	14.9%
Class II [201-500 heads]	24	63.2%	6 876	287	66.4%
Class III + 501 heads	3	7.9%	1 938	646	18.7%
Total	38	100%	10 361	273	100%

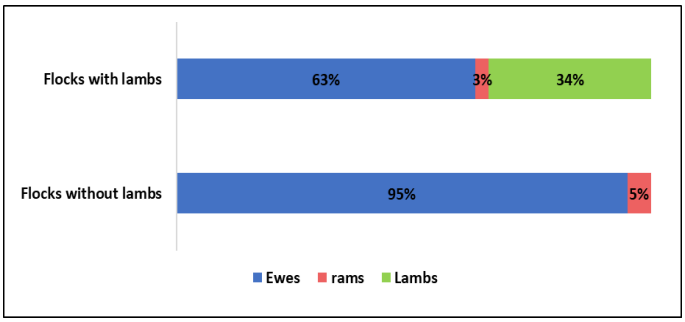

Figure 5: Sheep composition of managed flocks.

DISCUSSION

Geographic determinants of rental preferences

The comparative analysis of M'Kimen and Saouas reveals distinct patterns in tenant origins and exploitation methods, highlighting adaptive strategies employed by breeders integrating fenced resources into their livestock systems. The significant presence of Djelfa breeders (60% at M'Kimen) reflects the region's strategic location along established migration routes toward Tell regions in northern Tiaret, coinciding with spring rental periods and summer stubble availability (Gaci *et al.*, 2021). In contrast, Saouas's geographic isolation (bordered by Chott El-Chergui on three sides) and distance from major migration corridors result in predominantly local (94.7% Tiaret) patronage. Distant breeders conduct preliminary vegetation assessments before rental, while proximal breeders are motivated primarily by accessibility, a pattern consistent with the observations of Gaci *et al.* (2021) on transhumant breeders from Djelfa increasingly utilizing Tiaret's fenced pastoral as cost-reducing migratory stopovers.

Fodder scarcity as the primary driver of fencing utilization

Fodder availability in open rangelands significantly influences rental decisions. As open rangelands face continued degradation, securing fenced plots has become a nutritional necessity rather than an optional strategy, evidenced by high annual rental recurrence: 71% at M'Kimen and 82% at Saouas. The integration of fenced pastoral areas into routine management represents a qualitative shift in steppe pastoral systems from emergency drought mitigation toward institutionalized feed sourcing.

Administrative flexibility and environmental adaptation

A significant divergence exists between officially decreed and actual grazing periods, primarily stemming from delayed rental fee payments. Nevertheless, breeders appreciate this administrative flexibility as enabling adaptation to unpredictable environmental conditions. This contrasts sharply with the El-Bayadh region, where rigid fenced pastoral policies without adequate local alternatives triggered community protests during drought periods (Bencherif and Slimani, 2021), highlighting the critical importance of community acceptance for project success.

Persistent overgrazing: Mechanisms and implications

The core problem

Persistent overgrazing remains the fundamental concern limiting fencing effectiveness. Median stocking rates exceed carrying capacity by 60.4% at M'Kimen and 56.5% at Saouas across all exploitation modalities, and this overstocking is not randomly distributed but reflects systematic economic behavior.

Economic drivers

This overstocking reflects an economic calculus where high livestock value and low rental fees (fixed at 1,000 DA/ha since program inception) incentivize short-term

forage maximization despite long-term ecological costs (Habib *et al*., 2025). The fixed rental fee has not been adjusted for inflation or increased productivity, creating a misalignment between costs and benefits. As production costs increase (labor, feed, veterinary care), the rental fee represents a diminishing relative burden, further encouraging overstocking. The weak correlation between rented area and flock size at M'Kimen (R^2= 0.22, leaving 78% of variance unexplained) is consistent with this interpretation: flock sizes are primarily determined by historical herd composition and economic strategy, not by available rental area, meaning that even where area allocation is partially adaptive (r = 0.47, p = 0.02), it is insufficient to prevent systemic overloading.

Monitoring and enforcement challenges

The finding that exploitation modality does not significantly influence carrying capacity suggests that overgrazing is driven not by organizational structure but by systemic factors: insufficient real-time monitoring, weak enforcement of prescribed capacity limits, and lack of immediate consequences for violations. Beyond the ANOVA results, qualitative interview data reveal that co-sharing and co-usage modalities differ in meaningful ways. In co-sharing arrangements (M'Kimen), informal participants who lack formal tenure rights to the plot were less likely to raise concerns about collective flock overloading. The official renter bears legal responsibility but faces no effective mechanism to control the number of informal co-users. In co-usage arrangements (Saouas), where all participants hold official rental rights, access is more equitably distributed; however, no formal coordination mechanism exists to collectively limit total stocking. In both cases, the absence of binding collective agreements or effective real-time enforcement produces the same outcome: systemic overstocking. No formal disputes were reported, but informal tensions related to flock mixing and forage competition were acknowledged by several respondents. Supplement use rates were similarly high across both modalities, confirming that the fodder deficit driver is systemic and independent of governance modality.

Feed supplementation as symptom, not solution

The fact that 95.8% at M'Kimen and 92.1% at Saouas of tenants supplement with concentrated feed indicates widespread awareness of fodder deficits. However, supplementation fails to fully bridge the gap: deficits of 20.3% (M'Kimen) and 17.9% (Saouas) remain despite supplements. This practice, common across steppe regions (Hadbaoui *et al*., 2020; Senoussi *et al*., 2014; Yabrir *et al*., 2015), demonstrates that breeders recognize constraints yet persist with overstocking, suggesting that economic pressures override sustainability considerations.

Flock composition, LU standardization, and stocking comparisons

The difference in flock management between the two sites with all M'Kimen breeders bringing entire flocks but 39.5% of Saouas breeders excluding lambs, raises the question of whether LU-based stocking comparisons are fully comparable. As noted in the Methods section, standardization used FAO (2011) static coefficients that do not capture metabolic variability within age and physiological classes. A flock composed predominantly of dry adult ewes has a lower effective forage demand per LU than one with a high proportion of lambs in rapid growth or lactating ewes. Despite the partial lamb exclusion at Saouas, that site still records a higher median stocking rate (2.48 vs. 1.75 LU/ha), which points to other dominant factors: smaller average parcel sizes at Saouas, a fixed parcel constraint effect (reflected in the non-significant area-flock correlation at Saouas), and potentially higher absolute flock densities. Future assessments would benefit from metabolically adjusted LU conversion factors to improve cross-site comparability.

Mechanistic explanation: Four hypotheses

The persistent overgrazing despite awareness and administrative structures can be explained through four interconnected mechanisms:

Hypothesis 1: Tragedy of the Commons: Individual breeders lack incentive to reduce stocking because benefits of additional animals accrue to themselves while degradation costs are shared across all users. Without binding collective agreements or enforcement, rational individual behavior produces collectively irrational outcomes.

Hypothesis 2: Economic Necessity: For many tenant breeders, maximizing immediate forage extraction from fenced areas is essential for household survival and economic viability. Reducing stocking to sustainable levels may be economically unfeasible given market prices, production costs, and limited access to credit or alternative income sources.

Hypothesis 3: Institutional weakness: Institutional capacity constraints prevent effective real-time monitoring and enforcement. The organization oversees vast territories with limited field staff. Breeder violations carry minimal or delayed consequences, reducing deterrent effect.

Hypothesis 4: Structural market failure: The fixed rental fee (1,000 DA/hectare unchanged since inception) creates misalignment between ecological carrying capacity and economic incentives. As barley prices rise and labor costs increase, the rental fee represents diminishing relative cost, encouraging overstocking relative to the true ecological cost of rangeland degradation.

These hypotheses are not mutually exclusive; they interact

to produce the observed overgrazing pattern.

Limitations

This study is subject to several methodological limitations that should be considered when interpreting the findings. First, data were collected during a single spring rental season at each site (2017 at M'Kimen; 2018 at Saouas). Inter-annual variability in rainfall and fodder production both of which can substantially influence rental decisions, stocking behavior, and vegetation conditions is therefore not captured. These single-year cross-sectional snapshots may not fully represent long-term management dynamics. The high proportions of breeders with recurring annual rental patterns (71% at M'Kimen, 82% at Saouas) provide indirect evidence of behavioral stability across years, but multi-year longitudinal datasets would substantially strengthen inferences about recurring use and long-term stocking trends. Future research should prioritize multi-year monitoring designs spanning years of contrasting rainfall to disentangle structural from meteorologically-driven management decisions. Second, livestock unit standardization relied on static FAO coefficients, which may not capture metabolic variability within age classes (discussed above). Third, the cross-sectional interview design captures stated intentions and practices but may be subject to reporting bias.

Policy recommendations

Overgrazing stems from systemic governance failures requiring integrated reform. The following evidence-based measures address economic, monitoring, and institutional root causes:

- Real-time enforcement requires GPS collars, Sentinel-2 NDVI tracking, and breeder reporting apps, coupled with transparent penalty systems for rapid violation response.
- Incentive mechanisms include capacity-compliant fee discounts, sustainability certification for premium sheep products, and breeder associations managing rotational grazing allocations.
- Participatory governance mandates formal breeder councils with authority over rentals, annual condition assessments, and public data dashboards tracking vegetation recovery.
- Economic diversification promotes certified organic meat, cooperative marketing, medicinal plant cultivation, and microcredit to reduce overstocking pressure through alternative income streams.

CONCLUSION

This study provides a field-based assessment of the use of fenced pastoral areas in steppe sheep breeding systems, revealing significant differences in the origins of tenant breeders, forms of exploitation, and flock characteristics. The results confirm the economic importance of renting these areas for breeders in steppe environments and document the shift from emergency drought mitigation toward institutionalized feed sourcing.

The alarming finding that even fenced rangelands experience high animal pressure during rental periods with stocking rates exceeding carrying capacity by over 60% demonstrates that fencing alone is insufficient without stricter capacity enforcement and improved management practices. This observation indicates that the fencing restoration strategy, while ecologically sound in principle, is undermined by systemic factors: economic incentives favoring overstocking, weak monitoring and enforcement, and top-down governance lacking breeder participation.

This research contributes foundational understanding of fenced pastoral utilization patterns and identifies critical barriers to achieving sustainability. The findings serve as an evidence base for policy innovation and management strategy development. The persistence of overgrazing despite awareness, administrative structures, and economic stakeholder interest illustrates the complexity of managing common pool resources under economic scarcity and limited state capacity.

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NOVELTY STATEMENT

This study provides the first field-based, socio-ecological assessment of fenced pastoral area use by tenant breeders in the Algerian steppe, integrating breeder profiling, stocking rate analysis, and exploitation modality characterization within a single framework. Unlike prior studies focused exclusively on biophysical restoration outcomes, this work quantifies the human dimensions of rangeland degradation specifically the economic mechanisms, governance gaps, and behavioral patterns driving systematic overgrazing (60.4% above carrying capacity at M'Kimen; 56.5% at Saouas) despite breeder awareness of capacity limits. The study identifies the institutionalization of fenced pastoral areas as routine feed sources a qualitative shift from emergency drought mitigation and proposes evidence-based policy recommendations including dynamic fee structures, real-time monitoring, and participatory governance as novel management levers for sustainable steppe pastoral systems.

AUTHOR'S CONTRIBUTION

The manuscript was edited and revised by all authors.

Consent for publication

All authors declare their consent for publication.

Generative AI and AI assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Abbas K (2004). Degradation of steppe rangelands. Pour une lecture différente du rôle de l'élevage. Fourrages, 180 : 541-556.

Aïdoud A, Le Floc'h É, Le Houérou HN (2006). The arid steppes of North Africa. Sécheresse, 17(1): 19-30.

Amghar F, Langlois E, Forey E, Margerie P (2016). Defensing and fodder planting: Two restoration methods to improve vegetation, fertility and soil surface condition in Algerian arid rangelands. Biotechnol. Agron. Soc. Environ., 20(3): 386-396. https://doi.org/10.25518/1780-4507.12576

Badaouy AE, Khaliki YE, Geurtaoui FZ (2023). Les agdals, patrimoine commun: levier de développement du tourisme durable; Gestion, Préservation et Valorisation. Cas de du Haut Atlas central, Maroc. Espace Géogr. Soc. Marocaine, 1(79).

Bencherif S, Slimani H (2021). La gestion des espaces pastoraux en Algérie : Dynamique et stratégies des acteurs. Cahiers de la Méditerranée, 102. https://doi.org/10.4000/cdlm.14110

Chaieb M (1989). Influence des réserves hydriques du sol sur le comportement comparé de quelques espèces végétales de la zone aride tunisienne. Thesis, Université des Sciences et Techniques de Languedoc, Montpellier.

Doghbage A, Kouba Y, Salemkour N, Merdas S, Boukerker H, Chenchouni H, Habib B, Safi R, Djoughlafi A, Aidoud A, Sakaa B, Soufan W, Belhouadjeb FA (2024). Short-term grazing exclusion in arid rangelands affected soil surface conditions, plant community diversity and ecosystem services. Livest. Res. Rural Dev., 36, Article #60. http://www.lrrd.org/lrrd36/5/3660Abde.html

FAO (2011). Guidelines for the preparation of livestock sector reviews. FAO animal production and health paper No. 144. Food and Agriculture Organization of the United Nations, Rome, Italy. 56 pp. https://www.fao.org/4/i2294e/i2294e00.htm

Ferchichi A, Abdelkebir S (2003). Impact de la mise en défens sur la régénération et la richesse floristique des parcours en milieu aride tunisien. Sci. Changements Planétaires/ Sécheresse, 14(3): 181-187.

Gaci D, Huguenin J, Kanoun M, Boutonnet J-P, Abdelkrim H (2021). Nouvelles mobilités pastorales: Cas des éleveurs d'ovins de la wilaya de Djelfa, Algérie. Revue d'élevage et de médecine vétérinaire des pays tropicaux, 74(1): 3-11. https://doi.org/10.19182/remvt.36324

Habib B (2012). Evaluation of the public policy of fodder planting and fencing in Algerian steppe areas. Cas de la wilaya de Djelfa région de Zaâfrane et Deldoul. Magistère, ENSA, 146p. http://dspace.ensa.dz:8080/jspui/bitstream/123456789/2157/1/HABIB_Benbader

Habib B, Benmehaia MA, Saâdaoui M, Elhassani MK, Djoughlafi A, Doghbage A, Zemour H, Soufan W, Nazim M, Belhouadjeb FA (2025). Economic assessment of deferred grazing pasture system for rangeland restoration in steppe areas: A quantitative analysis. J. Aridl. Agric., 11: 17–28. https://doi.org/10.25081/jaa.2025.v11.9186

Hadbaoui I, Senoussi A, Huguenin J (2020). Les modalités d'alimentation des troupeaux ovins en steppe algérienne, région de M'Sila : Pratiques et tendances. Cahiers Agric., 29: 28. https://doi.org/10.1051/cagri/2020027

HCDS (High Commission for Steppe Development) (2010). Technical Guidelines for Pastoral Fencing Management. Algerian Ministry of Agriculture.

HCDS (High Commission for Steppe Development) (2019). Map of the department of Tiaret, paper document.

Kouba Y, Merdas S, Mostephaoui T, Saadali B, Chenchouni H (2021). Plant community composition and structure under short-term grazing exclusion in steppic arid rangelands. Ecol. Indicat., 120: 106910. https://doi.org/10.1016/j.ecolind.2020.106910

Le Houérou HN (1969). La végétation de la Tunisie steppique. Annales de l'Institut National de la Recherche Agronomique de Tunisie, 42: 1–624.

Lhoste P (2001). L'étude et le diagnostic des systèmes d'élevage. Atelier de formation des agronomes SCV, Madagascar, 1-32.

MADR (Ministry of Agriculture and Rural Development) (2020). Statistiques agricoles, Série B, Algérie. https://madr.gov.dz/wp-content/uploads/2022/04/SERIE-B-2019.pdf

Nedjraoui D, Bédrani S (2008). La désertification dans les steppes algériennes: Causes, impacts et actions de lutte. VertigO - la revue électronique en sciences de l'environnement, 8(1). https://doi.org/10.4000/vertigo.5375

Senoussi A, Hadbaoui I, Huguenin J (2014). Pastoral space in the M'sila region, Algeria: Status and rehabilitation prospects. Livest. Res. Rural Dev., 26(206). http://www.lrrd.org/lrrd26/11/seno26206.html

Yabrir B, Laoun A, Chenouf NS, Mati A (2015). Characteristics of sheep breeding in the central steppe of Algeria in relation to the aridity of the environment: the case of the wilaya of Djelfa. Livest. Res. Rural Dev., 27(207). http://www.lrrd.org/lrrd27/10/yabr27207.html

Yerou H, Belgharbi B, Homrani A, Miloudi A (2022). Impact de la restauration par mise en défens sur les potentialités pastorales d'un parcours steppique à dominance d'Artemisia herba alba dans l'Algérie occidentale. Livest. Res. Rural Dev., 34: Article #8. http://www.lrrd.org/lrrd34/2/3408hour.html