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Comparative Agronomic Practices and Swot Analysis of Forage Production Systems in The Algerian Steppe

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The Algerian steppe faces increasing pressure on forage production due to water scarcity and reliance on traditional agricultural practices. This study compares forage production systems in two irrigated zones Maadher-Bousaada and Khettala-Messaad through farm surveys and SWOT analysis. Results from 30 farms reveal contrasting models: Bousaada benefits from strong infrastructure and government support but remains dependent on conventional methods, while Messaad adopts a flexible, self-financed approach integrated with sheep farming. Key challenges in both regions include limited water resources, insecure land tenure, and low adoption of certified seeds and crop rotation. Despite these constraints, the study identifies several practical opportunities, including targeted government support, improved water management, and adoption of sustainable practices. The findings highlight the need for region-specific strategies to enhance forage productivity and resilience in arid environments.

Keywords: Algerian steppe; forage production; livestock farming; SWOT analysis

I. INTRODUCTION

Livestock farming is a major component of the global agricultural landscape, providing a critical source of income and nutrition for many people worldwide (Capstaff & Miller, 2018).

Forage refers to plant-based feed for livestock, particularly herbivores such as cattle, sheep, and horses. It consists of various types of vegetation, rich in fibres and essential nutrients, and can be used fresh, preserved, or grazed (Cauty & Perreau, 2009). The primary objective of forage production is to meet the quantitative and qualitative nutritional needs of herbivorous livestock, with the choice of production depending on the type of prairie type, forage species, and intended use (Huyghe, 2003).

Globally, livestock lands cover approximately 3.5 billion hectares, representing 70% of agricultural surfaces. Forage production is crucial for the sustainable development of warm regions and plays a vital role in integrated crop-livestock systems (Mebarkia *et al.*, 2020). Moreover, the success of livestock businesses is heavily dependent on effective feed management (Afriani et al., 2023).

In arid zones, water scarcity is the defining factor of forage systems; leading to two main categories rainfed and irrigated forage. These two separate forage systems form the foundation of various significant economic sectors that generating products for different markets, including both international and domestic markets (Putnam & DelCurto, 2020). However, recent changes in pastoral systems, particularly in North Africa, show a decrease in grazed

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fallow, natural prairies, and rangelands due to various factors, including public subsidies favouring cereal cultivation without considering the entire production system (Mebarkia *et al.*, 2020).

Focussing on Algeria, forage crops and fodder plants play an important role in supplementing animal feed in the steppe region, where breeders use resources like alfalfa hay, oat hay, and barley to compensate for the declining contribution of natural rangelands to livestock nutrition (Slimani *et al.*, 2021). Despite these efforts, feed costs represent 25-70% of total animal production expenses, with limited forage and pastoral production often hindering livestock development (Djennane *et al.*, 2022). The areas of forage have grown from 669,490 ha in 2010 to 959,841 ha in 2019, a 43.36% increase. However, this increase has not resolved issues in animal feeding; as there remains a forage deficit estimated at 3,124,273,725 forage units (ITELV, 2012). Forage production rose from 31 million quintals in 2010 to 52.6 million quintals in 2019, a 67% increase (Saad, 2023).

To address these challenges and improve milk and meat production while reducing forage import dependency, Algeria could implement various strategies. These include utilising quality seeds, efficient irrigation systems, fertilisers, crop rotation, forage conservation techniques, and selecting locally adapted forage plant species (Amrouni, 2020). Furthermore, the implementation of advanced agronomic techniques, such as optimised tillage, nutrient management, and precise seeding, can significantly enhance both the quantity and quality of fodder, ultimately leading to increased livestock productivity (Kumar *et al.*, 2018).

The steppe region in central Algeria faces unique challenges in forage availability due to arid conditions and traditional livestock practices. Improving forage cultivation practices in this area is crucial for meeting growing demand for animal products while ensuring the sustainability of local livestock systems (Hassen *et al.*, 2021).

The purpose of this study is to compare and diagnose forage crop production within the irrigated perimeter of Maadher- Bousaada, Algeria and Khettala-Messaad. The research includes: Characterisation of cultivated forage species (oats, alfalfa, barley, corn and sorghum), including adaptation to arid conditions and yield potential.

Analysis of socioeconomic factors that influence crop yields. An evaluation of current agronomic practices in forage production. A SWOT analysis of forage production methods was used to identify potential optimisation opportunities. The development of evidence-based recommendations to improve forage crop yields and sustainability. Farm surveys, focussing on operations producing forage and raising cattle, were conducted in collaboration with local dairy complexes and agricultural services. This interdisciplinary approach combines agronomic, socioeconomic, and strategic analyses to improve forage production in arid regions.

II. MATERIALS AND METHOD

A. Presentation of Study Region

Bousaada is located in an arid zone where the temperatures vary greatly by season. In winter, minimum temperatures can reach 6.1°C, while maximum temperatures are around 48°C (2021). It is a varied and complex territory characterised by wadis, mountains, and dunes. Its climate is marked by pronounced drought, with rare and irregular precipitation averaging 178.95 mm/year, very hot summers, and cold winters (Ouzir, 2023).

Messaad region, located in Algeria's central steppe zone, faces poor soils, low organic matter content, and low phosphorus levels. The eight-month dry season, from April to November, is characterised by a significant water deficit and high temperature differential. The region transitioned from a lower semi-arid bioclimatic stage to a middle arid stage between 1975-1996 and 1997-2018, largely due to temperature and precipitation changes (Lahoual *et al.*, 2015; Lahouel & Belhadj, 2022).

B. Study Design and Data Collection

A survey was conducted between February 15 and August 29, 2024, targeting thirty farms across two main agricultural perimeters: Maadher (Bousaada, M'sila Province) and Khettala (Messaad, Djelfa Province), as illustrated in Figure 1. Farm selection focused on active agricultural areas within these perimeters, with specific goal of including farmers engaged in both livestock farming and forage crop production. The selection process aimed to ensure

representativeness by including the full range of crop varieties and farming practices commonly used in both regions. Additional selection criteria considered farmer accessibility and willingness to participate, as well as practical access to farm locations. Remote or isolated areas with significant logistical challenges were avoided to ensure survey feasibility.

Building on this farm-level data collection, our study employed a systematic, multi-step approach to gather and analyse comprehensive information on agricultural practices in both regions, as shown in Figure 2. Structured interviews were conducted with six key agricultural stakeholders (n=6), evenly distributed between Bousaada and Messaad. These stakeholders comprised four agricultural engineers and two municipal technical delegates, providing expert insights that complemented the farm-level observations.

To evaluate these agricultural systems comprehensively, the SWOT (Strengths, Weaknesses, Opportunities, Threats) framework was employed. This analytical method, developed in the 1960s (Schendel, 1994), was specifically applied to optimise forage crop production strategies in both study perimeters.

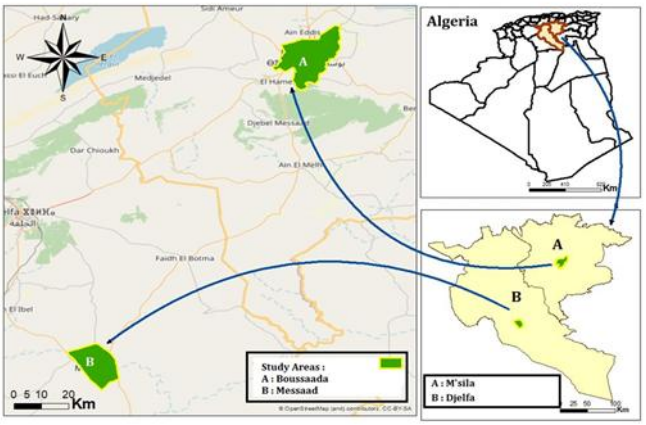

Figure 1. Geographical location of the two study perimeters.

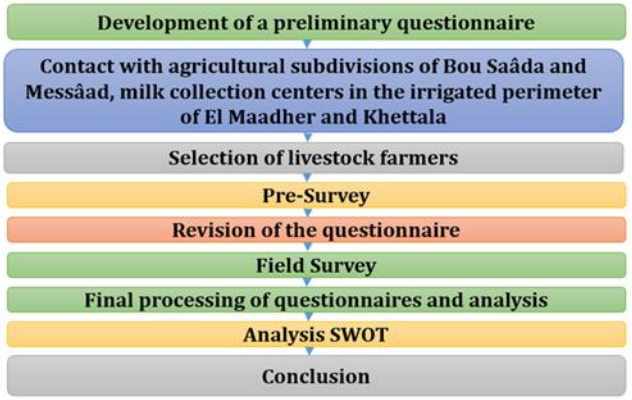

Figure 2. Flowchart of the methodological approach.

C. Data Analysis

Data collected from the farm surveys were compiled and analysed using Microsoft Excel 2013. The analysis focused on descriptive statistics, including the calculation of means, standard deviations, and percentages, to summarise and compare the socio-economic profiles, land use, and agricultural practices between the Bousaada and Messaad regions.

III. RESULT AND DISCUSSION

A. Socio-economic Profile

Table 1. Comparative socio-economic profile of surveyed farmers

Characteristic	**Bousaada (n=15)**	**Messaad (n=15)**
Age (years)		
Mean ± Standard Deviation	46,46 ± 10,41	45,86 ± 10,13
Median [min - max]	43 [24 - 59]	47 [29 - 64]
Gender, n (%)		
Male	15(100%)	15 (100%)
Female	00 (0%)	00 (0%)
Educational level, n (%)		
No formal education	03 (20%)	04 (27%)
Primary education	02 (13%)	01 (07%)
Secondary education	10 (67%)	07 (46%)
Higher education	00 (00%)	03 (20%)
Funding		
Self-funding	00 (00%)	15(100%)
State subsidies	15 (100%)	00 (00%)

Labor		
Permanent workers		
Mean ± Standard Deviation	07 ± 03,74	04,6 ± 05,27
Median [min - max]	05 [04 - 12]	3 [0 - 12]
Seasonal workers		
Mean ± Standard Deviation	00	07,42 ± 03,73
Median [min - max]	00	08 [01 - 12]
Machinery, n (%)		
Owen equipment	06 (40%)	03 (20%)
Rental	09 (60%)	12 (80%)

Table 1 summarises the socio-economic profile of the surveyed farmers in both regions, revealing demographic similarities (average age: ~46 years; 100% male) but marked contrasts in financing and operational structure. Bousaada relies entirely on state subsidies, while Messaad is 100% self-financed. Educational disparities are notable: Bousaada has a higher rate of secondary education (67% vs 46%), while Messaad has more higher education graduates (20% vs 0%). The workforce structure differs significantly: Bousaada employs more permanent workers (7-± 3.74 vs 4.6 ± 5.27) without using seasonal workers, unlike Messaad (average of 7.42 ± 3.73 seasonal workers).

The dependence on equipment rental is more pronounced in Messaad (80% vs 60%). Livestock practices differ considerably: Bousaada focuses on cattle (302) and sheep (390), while Messaad favors sheep (750) and goats (303), with only a small number of equines present.

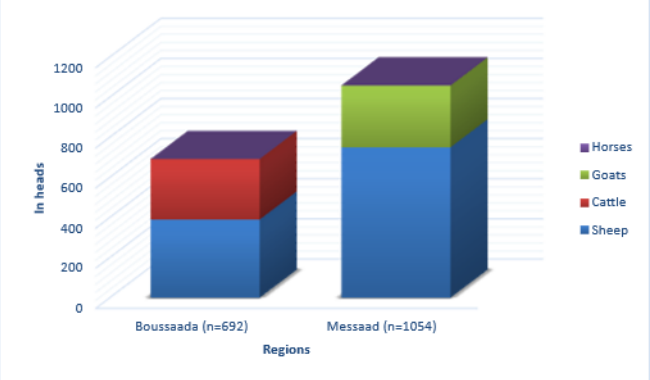

Figure 3 . Composition of livestock in the surveyed farms of Bousaadaand Messaad.

B. Land Tenure

Table 2. Land tenure status of surveyed farmers.

Legal Status, n (%)	Bousaada (n=15)	Messaad (n=15)
Law 83-13	00(00 %)	12 (80%)
Private	13(86 %)	00 (00%)
Concession	1(07 %)	03(20 %)
Rental	1(07 %)	0(00 %)

Land tenure status in Bousaada and Messaad shows different legal regularisation processes for agricultural areas. Although 86% of Bousaada farmers declare their land private, this usually refers to informal or customary occupation without legal regularisation. Most surveyed farmers have not regularised their status under Law 83-18 of August 13, 1983, on land development, or Circular No. 750 of August 18, 2018. They still favour the previous Law 83-18, preferring full ownership transfer to a 40-year concession.

In Messaad, 80% of farmers have regularised their land under Law 83-18, while 20% have chosen the concession system. This shows a desire to gain legal status at the expense of time-limited usage rights and tighter incorporation into state legislative systems.

In addition to differing land tenure patterns, land security perceptions differ. Bousaada farmers want full and permanent ownership for stability and intergenerational transfer, while Messaad farmers are more open to land reform. These findings emphasise the need for flexible and diverse land policies that reflect local circumstances and farmer desires, especially in fragile steppe areas where agricultural sustainability depends on land clarity and tenure security.

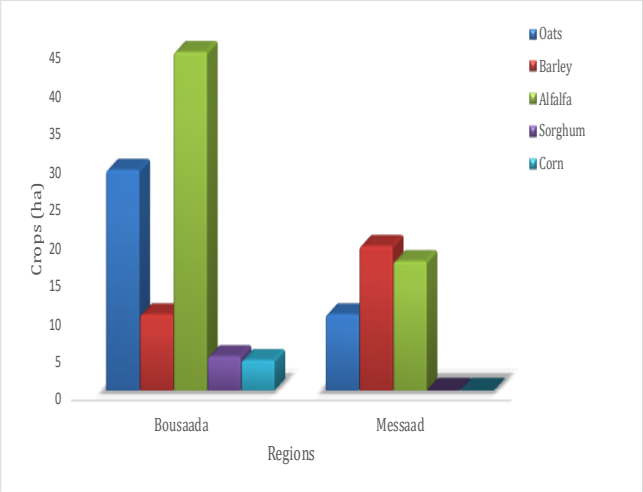

Figure 4. Cultivated land area allocated to different forage crops.

As shown in Figure 4, in Bousaada Maadher's perimeter, the average areas assigned to oats, barley, and Alfalfa were 1.93 ha, 0.67 ha, and 2.97 ha, respectively, with oats having the most variability (Std = 2.5 ha) and a maximum of 8 ha. Alfalfa likewise had a large land allocation, with a maximum of 09 ha, while sorghum and corn were produced on smaller areas, with mean values of 0.5 ha and 0.27 ha, respectively. The Khettala perimeter in Messaad, on the other hand, prioritized barley (mean = 1.27 ha, standard deviation = 2.15 ha), with a maximum of 7 ha. Oats and lucerne were less common, averaging 0.67 ha and 1.13 ha, respectively. Both areas used various farming systems based on local agricultural demands which are primarily driven by the type of livestock raised. The differences in crop allocation between the two perimeters can be directly linked to the composition of their respective livestock populations. Bousaada, with a significant proportion of cattle (44%), focuses heavily on Alfalfa. Additionally, sheep represent 56% of livestock in Bousaada. This contributes to the moderate allocation of oats (29 ha), a crop that can serve both cattle and sheep.

However, Messaad tailors its agricultural strategy to meet the needs of its predominantly sheep (71.2%) and goat (28.7%) population. Barley, which occupies 19 ha, is a well-suited feed crop for these ruminants. Goats, in particular, can thrive on rougher forage and are less dependent on high-protein crops like Alfalfa, which explains Messaad's lower total Alfalfa area (17 ha). The absence of cattle in Messaad supports this reduced emphasis on Alfalfa. Furthermore, the relatively lower oat cultivation in Messaad can be attributed to the fact that oats are not as critical for sheep and goats as they are for cattle.

Selecting appropriate crops and varieties is as important for increasing forage production as it is for improving grain yields.

C. Crop Allocation

The Table 3 shows comparative data for commune crops and highlights significant disparities in agricultural practices between Bousaada and Messaad, specifically regarding sowing seasons, planting densities, and irrigation schedules. Bousaada has enhanced adaptability, characterised by varying planting densities and irrigation frequencies across crops, particularly Avena sativa and Medicago sativa. This flexibility may lead to increased production variability in some crops. Conversely, Messaad adheres to more systematic and controlled methodologies, particularly in irrigation, as seen by Hordeum vulgare and Medicago sativa, leading to more steady yields.

The data indicates that Bousaada 's flexible strategy may be a reaction to varying environmental conditions, facilitating resource optimisation as required. In contrast, Messaad's systematic agricultural techniques demonstrate a more consistent administration of water and cultivation procedures, perhaps attributable to stricter environmental regulations. The table evidences these tendencies, illustrating how each region equilibrates production and resource management.

Table 3. Comparison of agronomic practices for common forage crops in the Bousaada and Messaad regions.

Crop	Aspect	Bousaada	Messaad
Oats	Sowing	September to October	Early October
	Seeding density	2 to 3 qx/ha	1 to 1.5 qx/ha
	Sowing depth	3 to 10 cm	3 to 5 cm
	Irrigation	Every 3 to 10 days	5 times per month, 7 hours
	Harvest	In May (around 5 months)	90 days after sowing

	Yields	200 to 400 bales/ha	175 to 200 bales/ha
Barley	Sowing	October	October
	Seeding density	1 qx/ha	2 qx/ha
	Sowing depth	5 cm	3 to 4 cm
	Irrigation	Every 3 days, 4 hours	Every 3-4 days, 6 hours
	Harvest	April-May (6 months)	Dual-use (1-3 months and June)
	Yields	120 bales/ha	Not specified
Alfalfa	Sowing	February, March, and September	October/March or March/October
	Seeding density	30 to 120 kg/ha	40 kg/ha
	Sowing depth	1 to 7 cm	4 to 5 cm
	Irrigation	Every 2 to 6 days, 2 to 6 hours	Every 5 days, 8 hours
	Harvest	Every 21 to 40 days	Every 35 days or from March to October
	Yields	100 to 250 bales/ha	175 to 220 bales/ha

Table 4. Specific crop practices in Boussaada.

Aspect	**Sorghum**	**Fodder Maize**
Sowing period	April to June	April
Sowing density	10 to 25 kg/ha	20 to 30 kg/ha
Sowing depth	5 to 7 cm	5 to 8 cm
Irrigation	Every 3 to 7 days, 2.5 to 5 hours	Every 7 to 8 days, 3 to 4 hours
Harvest	After 3 months	After 3 months
Yields	150 to 400 bales/ha	120 to 155 bales/ha

The Table 4 indicates significant differences in crop management practices between sorghum and fodder maize. Despite comparable sowing depths, their irrigation requirements vary considerably. Sorghum necessitates more frequent irrigation, indicating elevated water requirements. Additionally, the different management practices for these crops could provide farmers with a more stable income throughout the year.

D. Agricultural Practices

1. Fertilisation practices

The study indicates a clear preference for organic fertiliser (manure) in both locations, with Bousaada using it universally (100%) and Messaad almost as much (93.3%). However, the utilisation of NPK and urea 46 % exhibits large variability. While Bousaada relies totally on urea 46% (100%) with no recorded usage of NPK, Messaad diversifies its fertilisation strategy, with 40% of farmers utilising NPK, and 33.3% involve urea.

This implies that Bousaada favors a more traditional strategy, relying on manure and urea, likely influenced by local farming traditions. In contrast, Messaad appears to employ a mixed strategy, combining both NPK and urea, reflecting a need for more balanced nitrogen management or diverse crop requirements.

2. Crop rotation

In these locations, the vast majority of farmers do not practice crop rotation. However, this tendency is more pronounced in Bousaada, where 93.3% of farmers follow this approach, compared to Messaad, where the figure stands at 73.3%. This pattern demonstrates that monoculture represents the dominant agricultural method in both areas.

3. Certified seed usage

The usage of certified seeds remains notably low in both Messaad and Bousaada. Only 1 out of 15 farmers (6.7%) in Messaad use certified seeds, while in Boussaada there is no reported usage at all.

The low adoption of certified seeds in both areas highlights the need for greater awareness and access to improve overall productivity and sustainability.

4. *Irrigation methods*

All farmers in both regions use sprinkler irrigation (aspersion) for their crops.

5. *Forage crop calendar*

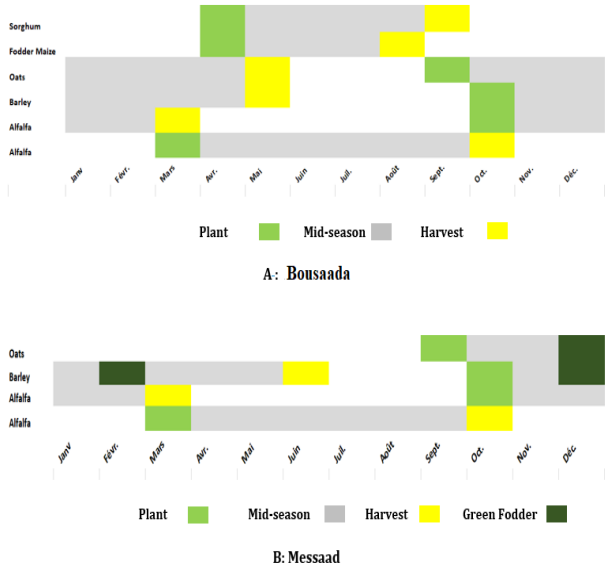

Figure 5. Forage crop calendar in both regions.

The provided forage crop calendars in Figure 5 highlight a heterogeneity of agricultural practices in the regions of Bousaada and Messaad, with distinct variances in crop selection and harvesting schedules. Moreover, this variation suggests a complex response to local environmental variables and a strategy for optimal resource utilisation across varied cropping systems. Furthermore, according to Slimani *et al.* (2021) livestock farmers supplement with rangeland-grown crops to meet nutritional needs, as natural rangelands' contribution decreases, necessitating diversification in animal feeding strategies.

E. Stakeholder and Agricultural Engineer Perspectives on Bousaada and Messaad Agricultural Systems

A qualitative assessment was conducted through structured interviews with six key agricultural stakeholders (n=6), comprising four agricultural engineers and two municipal technical delegates, equally distributed between Bousaada and Messaad regions. The SWOT analysis framework was employed to evaluate regional agricultural systems.

Table 5 summarises the SWOT analysis comparing forage production systems in Bousaada and Messaad. Bousaada appears to have a slight edge in terms of current development and infrastructure. Its capabilities in dairy production, established infrastructure, and good market access create a solid platform for agricultural success. However, its severe reliance on water resources in a water-scarce location is a huge long-term problem. Messaad, while having additional infrastructure issues, shows promise in its flexible and integrated farming method. The eventual resolution of land ownership concerns and chances for more government funding could lead to considerable changes in the future.

In light of the detailed analysis described above, several major facts arise regarding the agricultural practices in Bousaada and Messaad. Illustrating their distinct environmental, economic, and social contexts:

Socio-economic profiles: Although demographics are comparable, the financing mechanisms vary significantly; Bousaada depends on state subsidies, whereas Messaad is self-financed. This influences their methodology in agriculture and resource management.

Table 5. SWOT analysis of forage production systems.

SWOT Elements	**Bousaada**	**Messaad**
Strengths	• Excellent dairy basin • Well-developed infrastructure and irrigation • Strong agricultural tradition and local support • Good market access and dairy contracts	• Integration between fodder production and sheep farming • Stable local market for green fodder • Flexibility in production patterns (for self-consumption or sale)

Weaknesses	• Limited water resources and declining water table • Small farm sizes and land insecurity • Lack of equipment, capital, and technical knowledge • Monoculture and inefficient irrigation practices	• Land tenure issues and lack of legal ownership • Limited access to government support programs • High costs of agricultural inputs and equipment • Poor infrastructure (especially in energy and electricity)
Opportunites	• Government investment aids and subsidies • Growing demand for local animal and fodder products • Advancements in agricultural techniques • New road construction improving accessibility	• Potential resolution of land ownership issues • Chances to participate in government agricultural support and development programs • Possibility of engaging in production regulation and marketing guarantee programs
Threats	• Desertification and climate change impacts • Soil egradation and climatic risks • Price volatility and regional competition • Declining livestock numbers	• Competition from imported red and white meats • Potential decline in demand for local fodder • Price instability in the agricultural market

Land Tenure: Both regions encounter difficulties with informal land occupation, underscoring the necessity for land regularisation strategies tailored to local conditions.

Crop allocation: Differences in livestock composition drive crop selections. Bousaada relies on cattle-friendly crops like alfalfa, while Messaad promotes barley for its sheep and goat population.

Agricultural practices: Bousaada exhibits more flexible ways in sowing and irrigation, while Messaad adopts more systematic methods. This affects agriculture output and resource utilisation.

Both regions demonstrate a preference for organic fertilisers, limited crop rotation, and poor uptake of certified seeds. Irrigation methods are consistent (sprinkler); however, time varies.

SWOT Analysis: Bousaada benefits from increased infrastructure and market access but confronts water scarcity. Messaad shows promise in integrated farming but needs infrastructure.

These findings underline the necessity for specialised agricultural policies. Such policies must account for local characteristics, resource availability, and market demands. Future development policies should focus on three key areas. These include sustainable water management, land tenure resolution, and the promotion of diversified agricultural systems. These systems should be resilient and adapted to each region's particular characteristics.

F. General Discussion

In Algeria, the steppes were once excellent grazing lands (Nedjraoui, 2001), but recently they have faced significant problems related to pastoralism, socio-cultural changes, and the more recent effects of climate change (Siad *et al.*, 2022). This situation has created a strong interdependence between agriculture and livestock farming, with crops being cultivated to supply the feed needs of livestock (MADR, 2024).

Our results characterized the forage crop systems in two regions; the study involves characterising cultivated forage species such as oats, alfalfa, barley, corn, and sorghum, focusing on their adaptation to arid conditions and yield potential. It also analyses the socioeconomic factors affecting crop yields and evaluates current technical methods and agricultural practices used in forage production.

The results of socio-economic profile of farmers, showed demographic similarities in both regions regarding age (average age: ~46 years; 100% male). This average is lower than the mean age in Mediterranean region (average age: ~52 years; (Mohamed-Brahmi *et al.*, 2022), ~55 years (Guermah *et al.*, 2021) and ~57 years (Slimani *et al.*, 2021). Additionally, both regions have a higher rate of secondary education (Bousaada 67% vs Messaad 46%), compared to Mediterranean region, which characterised by relatively high illiteracy rate, particularly in Algeria (39%) and Tunisia (44%) (Mohamed-Brahmi *et al.*, 2022). In contrast, (Slimani *et al.*, 2021) report that in the steppe region, 32% are illiterate and have never attended school, 25% attended Koranic school, while the remaining 43%, the younger population, had different educational levels: primary, middle, secondary and even university.

The results of agricultural techniques in two studied regions showed a significant difference. As discussed earlier, Bousaada benefits from better infrastructure, while Messaad adopts a more flexible, self-reliant model.

This finding is consistent with the results of (Siad *et al.*, 2022), who report that the livestock systems in steppe territories are shifting towards more intensive forms. These trends appear as solutions for farmers seeking to improve their productivity in the face of various challenges. Conversely (Boussaada & Benabdelli, 2021; Guermah *et al.*, 2021; Mohamed-Brahmi *et al.*, 2022) report that farming systems in Algeria remain traditional extensive and are supplemented as needed,

For the Livestock practices, it differs considerably: Bousaada focuses on cattle (302) and sheep (390), while Messaad favours sheep (750) and goats (303), with a marginal presence of equines. This last result is consistent with the findings of (Boussaada & Benabdelli, 2021; Ouchene-Khelifi et al., 2021), which report that the majority of livestock in steppe region is mixed sheep and goats.

Land tenure in Bousaada remains largely informal, while Messaad shows greater legal regularisation under Law 83-18. These contrasts affect land security and agricultural planning. As optimal land use is vital for sustainability in arid areas (Abaidia *et al.*, 2020), clear and adaptable land policies are essential to reduce environmental stress and support livestock-based systems.

Our results showed that, despite similar climatic conditions, Bousaada and Messaad differ in crop choices, reflecting distinct land-use priorities and agronomic strategies. These differences are largely shaped by livestock composition: in Bousaada, where cattle represent 44% of the herd, alfalfa is prioritised, while oats serve both cattle and sheep.

In contrast, Messaad focuses on barley (19 ha) due to its predominately sheep (71, 2%) and goats (28, 7%) population, which require different feed types. Messaad places less emphasis on alfalfa and oats, as these are less essential for the livestock compared to cattle elsewhere. This result is in agreement with those of (Bensaha *et al.*, 2015), which report that the most common forage crop in the Saharan region is the barley, (Bensaha *et al.*, 2015), indicate that, the main obstacle to the improvement of animal production in these regions is poor livestock feed. Animal resources in Saharan regions have significant potential due to their good adaptation to environmental conditions, which deserves special attention from everyone.

For the analysis of essential practices such crop selection, sowing techniques reveals significant variations. Bousaada exhibits adaptability with changing sowing densities and irrigation frequency among crops, while Messaad conforms to methodical procedures, particularly in irrigation. Notably, both regions indicate a low adoption of certified seeds and crop rotation strategies.

SWOT analysis emphasises the strengths of Bousaada's infrastructure and market access, as well as Messaad's integrated manufacturing system. However, these regions confront shared limitations such limited water resources, land ownership concerns, and a lack of access to modern agricultural methods. Opportunities abound in government

investment and assistance programs, but dangers include desertification, climate change, and market instability.

This study contributes valuable insights into the relationship between traditional practices and contemporary challenges in the Algerian steppe. It underlines the need for specific solutions to boost forage production, promote sustainable agricultural methods in these areas.

IV. CONCLUSION

This study clarifies the distinct forage production systems in the Maadher–Bousaada and Khettala–Messaad regions of the Algerian steppe, highlighting the impact of socio-economic and environmental variables on agricultural resilience. Bousaâda is supported by state-funded infrastructure but is limited by water scarcity and conventional practices.

Conversely, Messaad demonstrates a more adaptable, autonomous system intertwined with cattle agriculture, with superior resource efficiency despite constrained capital.

The results suggest that sustainable development need specific policy interventions customised to these distinct geographical characteristics. The principal policy and practical consequences of this study are:

In Bousaada, interventions must focus on reallocating state subsidies from production volume to water-use efficiency, primarily by promoting the use of modern irrigation systems to alleviate severe water stress.

For Messaad, the most significant solution would be to enable access to state-supported capital investment projects, therefore overcoming fundamental restrictions in machinery and energy infrastructure that now impede its adaptive capacity.

A universally applicable, cost-efficient proposal for both regions is the enhancement of agricultural extension services to expedite the adoption of certified seeds and crop rotation, therefore immediately improving productivity and soil health.

This research emphasises the need to transcend a singular policy strategy. Adopting integrated, context-specific methods is crucial for boosting the sustainability of fodder production and livestock systems in dry locations. Future research should now focus on assessing drought-tolerant forage variety under these proposed management frameworks.

V. ACKNOWLEDGEMENT

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