

Sustainable sheep production in Algeria: mapping challenges and opportunities across the value chain

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Abstract

The sustainable development of the sheep sector in Algeria is crucial for rural livelihoods, food security, and ecosystem resilience. This study assesses the sector's sustainability using an integrated "One Health" and "value chain" framework combining economic, social, and environmental dimensions. Based on a multi-criteria analysis (Analytic Hierarchy Process, AHP), three development scenarios were evaluated: (1) the Business-as-usual model, (2) the Cooperative structure model, and (3) the Smart, traceable sector model. Primary data were collected from 200 farmers across three representative agro-ecological regions (High Plateaus, Aurès Mountains, and Southern Steppe zone) through structured surveys, 30 semi-structured interviews, and 3 regional focus groups. Complementary data from official statistics (MADR, 2023) and FAO reports (2022–2024) were analyzed using SPSS and thematic coding. Results show that the Smart, traceable sector scenario achieved the highest overall sustainability score (3.75/5), followed closely by the Cooperative structure model (3.70/5). Quantitatively, the analysis indicates that cooperative organization could increase average carcass yield by +12%, reduce post-weaning mortality by –8%, and improve farmers' income stability by +15% compared to the baseline scenario. These findings highlight the potential of digital innovation, collective organization, and coordinated governance to improve efficiency, resilience, and equity throughout the value chain. Policy recommendations emphasize the establishment of regional cooperatives, national traceability systems, and integrated livestock management platforms to ensure a more sustainable and inclusive future for Algeria's sheep sector.

Keywords: Sustainable livestock systems; Sheep value chain; Agricultural innovation; Smart farming; Multi-criteria analysis; One Health

Production ovine durable en Algérie : cartographie des défis et des opportunités tout au long de la chaîne de valeur

Résumé

Le développement durable du secteur ovin en Algérie est essentiel pour les moyens de subsistance ruraux, la sécurité alimentaire et la résilience des écosystèmes. Cette étude évalue la durabilité du secteur à l'aide d'un cadre intégré combinant l'approche « Une seule santé » (One Health) et l'analyse de la « chaîne de valeur », en intégrant les dimensions économique, sociale et environnementale. Sur la base d'une analyse multicritère (méthode du Processus Hiérarchique Analytique – AHP), trois scénarios de développement ont été évalués : (1) le modèle tendanciel (Business-as-usual), (2) le modèle coopératif, et (3) le modèle intelligent et traçable (Smart, traceable sector model). Les données primaires ont été collectées auprès de 200 éleveurs répartis dans trois régions agroécologiques représentatives (Hauts Plateaux, montagnes des Aurès et zone steppique méridionale), à travers des enquêtes structurées, 30 entretiens semi-directifs et 3 groupes de discussion régionaux. Des données complémentaires issues des statistiques officielles (MADR, 2023) et des rapports de la FAO (2022–2024) ont été analysées à l'aide du logiciel SPSS et d'un codage thématique. Les résultats montrent que le scénario du secteur intelligent et traçable obtient le meilleur score global de durabilité (3,75/5), suivi de près par le modèle coopératif

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(3,70/5). D'un point de vue quantitatif, l'analyse indique qu'une organisation coopérative pourrait augmenter le rendement moyen en carcasse de +12 %, réduire la mortalité post-sevrage de -8 %, et améliorer la stabilité des revenus des éleveurs de +15 % par rapport au scénario de référence. Ces résultats soulignent le potentiel de l'innovation numérique, de l'organisation collective et de la gouvernance coordonnée pour améliorer l'efficacité, la résilience et l'équité tout au long de la chaîne de valeur. Les recommandations politiques mettent l'accent sur la création de coopératives régionales, la mise en place de systèmes nationaux de traçabilité et le développement de plateformes intégrées de gestion de l'élevage afin d'assurer un avenir plus durable et inclusif pour le secteur ovin en Algérie.

Mots clés: systèmes d'élevage durables ; chaîne de valeur ovine ; innovation agricole ; agriculture intelligente ; analyse multicritère ; approche « Une seule santé ».

INTRODUCTION

Sheep farming holds a central position in Algerian agriculture, particularly across the steppe and semi-arid regions, where it contributes substantially to rural employment, income generation, and food security (Merrouchi et al., 2021; Meziane et al., 2024). According to the Ministry of Agriculture and Rural Development (MADR, 2023), the national flock is estimated at approximately 19 million head.

The sector has undergone significant transformations since independence in 1962: from state-managed breeding programs in the 1970s, to liberalization and privatization in the 1990s, and finally to modernization and food sovereignty strategies since 2020 (Bencherif et al., 2022; Bonnet et al., 2024). Despite these efforts, productivity remains low, largely due to extensive transhumant systems, dependence on imported feed, and weak institutional coordination.

Algeria's sheep population is composed primarily of local breeds such as Ouled Djellal (≈60%), Rembi, Hamra, Barbarine, and Tazegzawt, each adapted to specific ecological zones (INRAA, 2023). However, genetic erosion and unregulated crossbreeding threaten breed integrity and ecosystem resilience.

In this context of climate variability, resource scarcity, and increasing demand for animal protein, a transition toward sustainable sheep farming is indispensable. It must integrate economic viability, environmental stewardship, and social inclusion, aligning with the Sustainable Development Goals (SDGs 1, 2, 12, and 15).

The value chain approach (Porter, 1985; Kaplinsky & Morris, 2001) provides a systemic lens to analyze how value is created, distributed, and potentially lost across actors - from input suppliers to consumers. Yet, studies applying this approach to Algeria's ovine sector remain scarce. This research fills that gap by mapping challenges and opportunities along the chain and identifying strategic pathways for sustainability. This research is structured around three key questions:

1. How is the sheep value chain currently organized in Algeria, from upstream to downstream?
2. Where are the shortfalls, the hurdles, but also the untapped opportunities?
3. What strategies could lead to a more sustainable sector in the medium and long term?

MATERIAL AND METHODS

1. Literature review

The bibliographic research followed systematic review principles. Databases consulted included Google Scholar, Scopus, ScienceDirect, Web of Science, and AGRIS, covering publications from 2000 to 2024. Keywords combined terms such as “sheep”, “value chain”, “Algeria”, “sustainability”, and “livestock systems”. National sources (ONAB, INRAA, MADR) complemented this review with grey literature.

1.1. Sustainability of sheep farming systems

Applying the concept of sustainability to livestock involves assessing economic, social, and environmental performance, often referred to as the “triple bottom line” (Elkington, 1997; Smith et al., 2019). In the North African context, several studies have emphasized the vulnerability of extensive sheep farming systems due to increasing aridity, pasture degradation, and market price instability (Ben Salem et al., 2010). In Algeria, the National Office for Meat and Food (ONVA) has expressed concern about the decline in per-head productivity, compounded by irregular health management and growing dependence on imported feed.

1.2. The value chain approach

Introduced by Porter (1985), the value chain concept provides a detailed breakdown of all steps from initial production to final consumption, highlighting where value is created or lost, power relations among actors, and potential improvement levers (Kaplinsky & Morris, 2001). While extensively applied to cereal, dairy, or cattle systems, studies specifically focused on the Algerian sheep value chain remain limited. Typically, the model distinguishes primary activities (production, collection, processing, distribution) from

support functions (logistics, financing, training, and regulation).

1.3. Regional insights and international comparisons

Research from neighboring Maghreb countries offers useful insights. In Morocco, cooperative development and local specialty meat promotion have improved smallholder incomes (Mahdi et al., 2017). In Tunisia, drought-resilient value chains supported by international donors such as IFAD demonstrate the benefits of combining local innovations with institutional support. At a larger scale, New Zealand represents a highly integrated model emphasizing traceability, export markets, and by-product valorization. These examples highlight that while opportunities exist for improvement, they must be adapted to local institutional and ecological realities.

To provide a realistic and systemic analysis of the Algerian sheep sector, this study adopts a mixed-methods approach, combining qualitative (interviews, observations) and quantitative (surveys, numerical data) tools. This combination ensures both analytical depth and empirical accuracy.

2. An analytical framework centered of the value chain

The value chain is defined as the full range of activities necessary to bring a product from input supply to final consumption. The analytical framework builds on Porter’s (1985) approach and its agricultural adaptations for developing countries (Kaplinsky & Morris, 2001).

For the sheep sector, six major segments were identified:

1. Input supply (feed, equipment, veterinary care)
2. Rearing and production (herd management, fattening)

3. Collection and transportation
4. Processing (slaughtering, cutting, packaging)
5. Distribution (markets, butcher shops)
6. Consumption

These segments are supported by cross-cutting services such as veterinary assistance, financing, training, and regulatory supervision.

3. Study area and period

The fieldwork was conducted from January to May 2025 across three representative regions of Algeria's main sheep farming systems:

1. High Plateaus (e.g., Sétif, Djelfa): semi-intensive systems with high livestock density and access to feed markets.
2. Aurès Mountains (e.g., Batna, Khenchela): traditional smallholder systems in mountainous areas, relying on communal grazing.
3. Saharan zone (e.g., Laghouat, El Bayadh): extensive pastoral systems dependent on natural rangelands and mobility.

These regions were selected to capture the diversity of agro-ecological and socio-economic conditions across the country. Furthermore, this diversity aligns with Algeria's official agricultural zoning, allowing results to inform regional and national livestock policies.

4. Data collection

Data was gathered through two main sources:

a) Secondary Data

These came primarily from official sources such as the Ministry of Agriculture and the National Office for Animal feed, as well as international organizations like the FAO and recent scientific articles. This information provided a general framework and allowed local results to be compared with other contexts.

b) Field Surveys

Quantitative survey: 200 farmers were selected using stratified random sampling proportional to regional flock density. Sample size was determined using Cochran's formula (95% confidence, 7% margin of error).

Semi-structured interviews: 30 key informants (veterinarians, traders, cooperative leaders, abattoir managers).

Focus groups: 3 workshops (one per region) involving 8-10 stakeholders to validate the chain mapping.

5. Data Processing and analysis

Statistical tests: Descriptive statistics and ANOVA were conducted using SPSS 29.0 to assess differences in production costs and yields across systems. Pearson correlation tested the relationship between farm size, input cost, and productivity.

SWOT quantification: SWOT indicators were weighted using expert elicitation (n=12) and normalized on a 5-point Likert scale to reduce subjectivity.

Multi-criteria analysis: The AHP (Saaty, 2008) was applied to integrate expert judgments and rank the three development scenarios.

Triangulation: Qualitative and quantitative data were cross-validated to improve reliability.

6. Methodological limitations

As with any field research, this study faces certain limitations:

1. Limited access to some sensitive data, particularly on actual prices and informal practices.
2. Seasonality: The survey took place outside of the Eid period, which means some indicators like prices, availability, and product flows might be underestimated.
3. Participation bias: Farmers who took part did so voluntarily, which could affect representativeness.

Nonetheless, the diversity of sources, the triangulation of methods, and the constant

cross-checking between data and testimonies add robustness to the analysis and help draw practical lessons for action.

RESULTS AND DISCUSSION

1. Understanding the sheep value chain in Algeria

Looking at the sheep sector through the lens of a value chain helps reveal how the different parts of the system connect, or, in many cases, fail to connect. It identifies areas of value addition and loss, which can at times be considerable. In Algeria, the chain is still largely fragmented, with limited coordination between actors and a heavy dependence on informal networks, which makes it difficult to build a structured and efficient system. Quantifying each stage of the value chain provides a clearer picture of where inefficiencies occur—particularly in feed costs, logistics, and post-slaughter processing. The AHP-based ranking confirmed that a gradual modernization through cooperatives (Scenario 2) is the most feasible short-term strategy, while the smart, traceable model (Scenario 3) offers

the highest long-term sustainability and innovation potential.

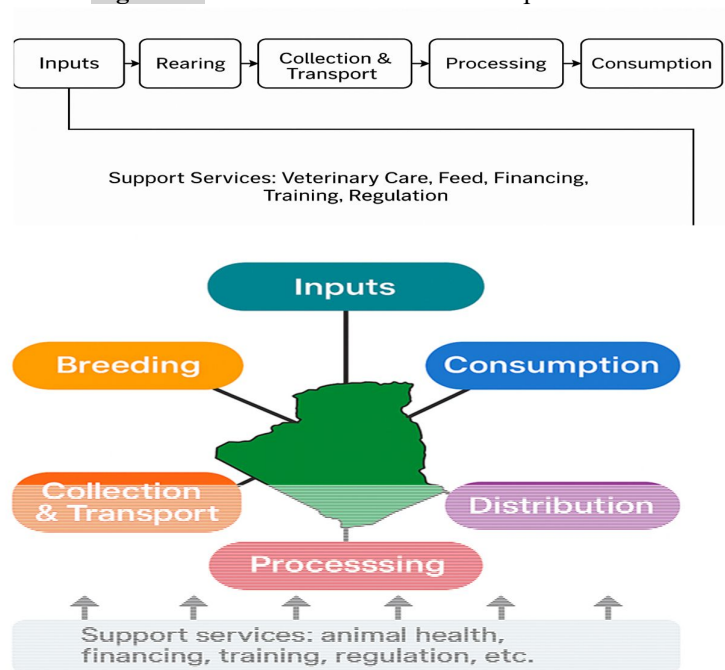
Integrating digital tools, agroecological practices, and cooperative governance could reduce national feed dependency by 20–25%, while improving traceability and export potential. These results converge with findings from Mahdi et al. (2017, Morocco) and IFAD (2022, Tunisia), confirming regional relevance.

Future research should extend to consumer behavior, carbon footprint quantification, and genetic resource management, providing a more holistic foundation for sustainable policy planning.

Broadly speaking, the value chain is made up of the following stages:

Supporting services such as veterinary care, animal feed supply, financing, training, and regulatory oversight cut across these different stages.

Figure 1 : Current structure of the sheep value chain



2. Input supply

This initial link in the chain includes everything farmers require to raise and maintain their livestock. Especially, feed (both forage and concentrated), veterinary medicines, basic farm equipment and sometimes access to genetic services like selected breeding animals or artificial insemination.

Most of these inputs come from private companies, usually located in urban centers, making the supply of rural and remote areas inconsistent. On top of that, there's a heavy dependence on imported products, especially corn and soybeans, making the system vulnerable to global market fluctuations. Small-scale farmers also struggle to access mortgage or tailored financing programs.

Altogether, inputs make up roughly 45 to 55 percent of total production costs, which weighs heavily on farmers' profit margins, especially given the ongoing inflation.

3. Livestock production

This is the core of the value chain, where sheep are raised, cared for, fattened, and eventually sold. There are generally three main types of production systems in place:

1. Extensive systems, mostly found in steppe or desert areas, rely on natural grazing.
2. Semi-intensive setups, more structured and often located in foothill regions or irrigated areas.
3. Intensive systems, which are still rare, tend to appear on the outskirts of urban centers and involve larger flocks.

Flock sizes typically range between 40 and 60 animals. Average carcass yields fall between 24 and 26 kilograms, while lamb mortality rates hover around 10 to 12 percent. Key challenges at this stage consist on limited access to veterinary services, poor reproductive management, and a lack of technical training for farmers.

4. Collection and transport

Once the animals are ready for sale, they're gathered and moved usually through informal means. Middlemen, known locally as "سماسرة - maquignons", handle most of this trade. There's little in the way of official contracts or documentation; transactions are based largely on word of mouth and direct negotiation.

Transport conditions are often far from ideal. Overloaded vehicles and long trips create stress for the animals and lead to weight loss, of 1 to 2 percent per day. On average, the livestock transport costs between 8 and 12 Algerian dinars per kilometer per animal

This stage is particularly vulnerable, as it involves significant value loss, largely due to poor coordination and lack of oversight across the chain.

5. Processing

Processing includes all activities occurring after slaughter, from meat cutting and packaging to the production of processed products like sausages or other prepared meats.

Two types of slaughtering practices are common; Public abattoirs exist, but many are outdated and underused. In contrast, informal slaughtering, often performed at home or in open markets, is widespread.

Fewer than 30 percent of sheep are processed in officially approved facilities. This has many consequences: hygiene standards are not always respected, there is virtually no health or halal certification, and by-products such as wool, hides, and fat are often wasted or poorly used.

6. Distribution

Sheep meat is mainly sold through livestock markets, traditional butcher shops, and temporary stalls that pop up during holidays like Eid.

Prices vary depending on location and time of year, ranging from 1,100 to 1,900 dinars per kilogram. Distributors typically take a margins of between 15 and 25 percent.

One of the main issues at this stage is the length and complexity of the distribution channels. Longer supply chains drive up prices for consumers, without necessarily improving meat quality or traceability.

7. Consumption

In Algeria, sheep meat is highly valued - not only for its taste but also for its strong cultural and symbolic significance. It's closely associated with key family and religious events such as Eid and weddings.

Current trends show several challenges:

1. Consumption is gradually declining, largely due to rising prices.
2. There is limited product diversification; halal charcuterie, ready-to-eat meals, and processed meat products are still underdeveloped.
3. Consumption patterns remain mostly occasional and traditional, which prevents the sector from expanding into new consumer segments or developing modern retail markets.
4. Cross-Cutting support services
Throughout the value chain, support services play a crucial role, though in practice they often fall short of what's needed.
 1. Animal health care: Public veterinary services are underfunded, and private services are often too costly for small-scale farmers.
 2. Access to finance: Agricultural credit is hard to come by, especially for smallholders.
 3. Training: Available programs tend to be overly theoretical and not adapted to the realities of rural livestock farming.



4. Technical guidance: In some areas, it's missing entirely; in others, it overlaps or lacks consistency.

5. Regulation: While standards for practices like slaughtering and traceability exist on paper, enforcement in the field remains weak.

6. SWOT Analysis of the sustainable sheep sector in Algeria

To better understand the internal and external dynamics of Algeria's sheep sector, a SWOT analysis is a useful instrument. It helps connect internal factors (what the sector can or cannot control) with external forces (opportunities to seize or threats to manage). Below is a summary of key findings:

6.1. Strengths (Internal positives)

1. Large national flock: With nearly 19 million head spread across the country, the sector has a solid production base.

2. Strong cultural roots: Sheep meat plays an essential role in Algerian traditions, especially during religious and family celebrations like Eid and weddings.

3. Local expertise: Generations of experience have shaped practices well-suited to dry and steppe ecosystems.

4. Seasonal demand peaks: Consumption tends to surge at key times of the year, creating dependable sales periods.

These cultural and structural foundations give the sector a certain resilience, even in the face of broader challenges.

Weaknesses (Internal negatives)

1. Low productivity: Carcass yields are modest, growth is slow, and post-weaning losses are significant.

2. Dependence on imported inputs: Feed (like maize and soy) and veterinary medicines mostly come from abroad.

3. Lack of organization: The supply chain is fragmented, and coordination between actors is weak or absent.

4. Informal dominance: A large share of sales and slaughter takes place outside regulated systems, with little to no traceability.

5. Limited financial access: Credit remains inaccessible to many small-scale farmers.

6. Underused by-products: Wool, hides, and offal are often discarded or poorly valorized.

These limitations prevent the sector from upgrading its value chain or reaching premium markets.

Opportunities (External positives)

1. Growing interest in short supply chains: Consumers are showing more interest in local, traceable products.

2. Policy shifts in agriculture: Food sovereignty and security are becoming national priorities.

3. Digital innovation: Tools like electronic identification, traceability systems, and veterinary monitoring are increasingly available.

4. Quality certification: Labels such as organic, certified halal, or regional origin could enhance market value.

5. Support from international donors: Many funders are prioritizing climate-resilient food systems.

6. Demand in export halal markets: Several Arab and European countries offer attractive opportunities for halal-certified meat.

If these trends are harnessed in time, they could revitalize the entire sector.

Threats (External risks)

1. Climate change: More frequent droughts, land degradation, and water scarcity threaten grazing systems.

2. Price volatility: The cost of imported inputs can fluctuate wildly, affecting farm profitability.

3. Animal disease outbreaks: Illnesses like brucellosis or sheep pox are often poorly anticipated or managed.



4. Lack of interest from young people: Livestock farming is often seen as hard, unprofitable, and undervalued.

5. Rising competition: Cheaper alternatives such as imported meat or poultry are more affordable for many households.

Without proactive planning, these risks could further destabilize an already vulnerable sector.

1. What does the SWOT reveal?

Algeria's sheep industry has important assets - but they remain underused or poorly connected. The challenge isn't to rebuild from scratch, but to create stronger links between stakeholders, reinforce the weaknesses (especially slaughtering, logistics, and training), and take benefit of new openings in quality certification, traceability, and innovation.

6. Development scenarios for a more sustainable sheep sector

To prepare for the future, it's helpful to explore possible development paths. These scenarios make it easier to plan for change, guide public and private decisions, and align interventions with realistic assumptions. Here are three potential directions:

Scenario 1: "Business as Usual"

1. SWOT link: This scenario reflects the continuation of current practices without addressing internal weaknesses or external threats. Weak coordination, informal trade, and underdeveloped infrastructure remain unaddressed, while external opportunities such as certification or digital tools are not exploited.

2. Overview: Minor improvements in traditional farming, marketing, and management practices.

3. Expected outcomes:

1. Stagnant productivity and product quality

2. Increased vulnerability to climate and market shocks

3. Consumer dissatisfaction due to lack of traceability and quality assurance

4. Limited investment in training or infrastructure

4. Main risk: Gradual loss of competitiveness, especially against low-cost imported meat

Scenario 2: "Gradual modernization"

Scenario 2: "Cooperative Structure / Gradual Modernization"

1. SWOT link: Directly addresses internal weaknesses by fostering cooperation among stakeholders, improving coordination, and formalizing trade. Selective adoption of modern technologies and better logistics tackle operational weaknesses.

2. Overview: Key technologies and practices are adopted selectively, including electronic tagging, improved genetics, and shorter supply chains. Initial stakeholder structuring and cooperative approaches are implemented.

3. Expected outcomes:

1. Improved yields and product quality

2. Better disease control and risk management

3. Emergence of local certification labels and regional market growth

4. Improved access to finance, training, and veterinary services

4. Strengths: Builds on local know-how while gradually introducing modernization

5. Limitations: Progress may be uneven across regions depending on engagement and resources

Scenario 3: "Smart, Traceable Sector / Ambitious Sustainable Transition"

1. SWOT link: Exploits external opportunities such as digital innovation, certification, and market trends, while also addressing key internal weaknesses in training, logistics, and value chain development.

2. Overview: Comprehensive transformation focusing on economic, social, and environmental sustainability.

3. Key actions:

1. Widespread adoption of agroecological practices

2. Development of strong local value chains and short circuits

3. Income diversification for farmers (e.g., agritourism, small-scale processing)

4. Use of digital tools for traceability, pasture monitoring, and animal health

5. Ambitious public policies supporting inclusive and innovative practices

4. Benefits:

1. Greater resilience to climate shocks

2. Strong product branding and added value

3. Social inclusion, particularly for women and young farmers

4. Enhanced contribution to national food security

5. Challenges: Requires long-term commitment and coordination across public, private, and civil society actors

Comparing Scenarios: Sustainability-Based Scorecard

Each scenario is evaluated across five criteria: economic viability, social equity, environmental impact, short-term feasibility, and innovation/competitiveness.

1. Scenario 1 (“Business as Usual”): Safe but limited; fails to address internal weaknesses and external opportunities; low long-term innovation.

2. Scenario 2 (“Cooperative Structure / Gradual Modernization”): Balanced; addresses internal weaknesses, builds stakeholder cooperation, and gradually exploits opportunities; feasible but requires active engagement.

3. Scenario 3 (“Smart, Traceable Sector / Ambitious Transition”): High economic and innovation potential; exploits opportunities fully and tackles weaknesses comprehensively; lower short-term feasibility due to structural and technological changes.

Conclusion: Scenario 2 offers the most balanced and feasible path forward, while Scenario 3 represents an ambitious, transformative vision for the sector’s long-term sustainability.

Table 1: Comparative assessment of development scenarios for the Algerian sheep sector based on key sustainability criteria

Scenario	Economic Viability	Social Equity	Environmental Impact	Short-term Feasibility	Innovation / Competitiveness
Scenario 1 (Basic Optimization)	● Good	● Poor	● Good	● Good	● Poor
Scenario 2 (Cooperative Growth)	● Solid	● Excellent	● Solid	● Moderate	● Strong
Scenario 3 (Smart Sector Model)	● Excellent	● Moderate	● Solid	● Low	● Excellent

Legend / Color Key:

- = Strong / Good performance
- = Moderate / Average performance
- = Weak / Low performance

8. Livestock production Strategic priorities for a sustainable and competitive sheep sector in Algeria

To ensure long-term sustainability and improve the competitiveness of Algeria's sheep industry, several priority areas must be addressed:

8.1. Institutional and regulatory reform

1. Establish a clear and coordinated governance framework that encourages dialogue between farmers, processors, and public authorities.

2. Develop and enforce appropriate hygiene and traceability standards.

3. Support the formation and formalization of cooperatives and professional organizations.

8.2. Technical modernization and innovation

1. Promote the use of digital tools such as electronic tagging and pasture management systems.

2. Encourage ongoing training for both livestock producers and veterinary technicians.

3. Invest in modern slaughter and processing infrastructure to improve efficiency and safety.

8.3. Financing and economic support

4. Improve access to tailored credit for small and mid-sized farmers.

5. Support public-private partnerships for innovative pilot projects.

6. Increase the value of sheep products through quality labels and short supply chains.

8.4. Environmental and social sustainability

1. Encourage agro-ecological practices and responsible resource management.

2. Promote the inclusion of youth and women across the value chain.

3. Support income diversification through rural tourism and the use of by-products like wool and hides.

4. AHP-Based scenario analysis

9.1. Method Overview

The Analytic Hierarchy Process (AHP) is used to break down complex decisions into a structured hierarchy. Each criterion is compared in pairs to determine relative importance, and then each scenario is scored accordingly. A composite score is calculated to support strategic decision-making.

a) Criteria selection Five main criteria were used to evaluate the scenarios.

Table (4) outlines the five key criteria used to evaluate development scenarios for the sheep value chain in Algeria. Each criterion reflects a distinct dimension of sustainability and competitiveness:

1. **C1. Economic viability** refers to the sector's capacity to provide farmers with a stable and reliable source of income, ensuring financial sustainability over time.

2. **C2. Social inclusion** measures how well the sector engages traditionally underrepresented groups, particularly

- small-scale producers, young people, and women.
3. **C3. Environmental impact** assesses the extent to which practices contribute to the sustainable use of natural resources and the adoption of environmentally responsible techniques.
 4. **C4. Operational feasibility** considers how practical and cost-effective it would be to implement each scenario,
 5. **C5. Market potential** captures the ability of the sector to access new and higher-value markets, enhance product differentiation, and expand export opportunities.
- Together, these criteria provide a comprehensive framework for comparing development paths and identifying the most balanced and impactful strategy.

Table 2: Definition of Evaluation Criteria for Scenario Assessment in the Algerian Sheep Sector

Criterion	Description
C1. Economic Viability	Ability to generate stable net income for farmers
C2. Social Inclusion	Level of participation by smallholders, youth, and women
C3. Environmental Impact	Reduction of pressure on natural resources and adoption of good practices
C4. Operational Feasibility	Ease of implementation, associated costs, and social acceptability
C5. Market Potential	Access to new markets, added value, and export readiness

b) Weighting the criteria Weights were assigned in consultation with experts to reflect the strategic importance of each criterion:

1. C1. Economic Viability: 30%
2. C2. Social Inclusion: 20%
3. C3. Environmental Impact: 20%
4. C4. Operational Feasibility: 15%
5. C5. Market Potential: 15%

These weights aim to strike a balance between sustainability and the need to ensure viability in often fragile rural settings

1. Scenario evaluation

Each scenario was rated from 1 to 5 (Table 3) across all criteria, where 1 is very poor and 5 is excellent. The ratings were based on empirical data and input from local stakeholders.

Table 3. Scenario scoring matrix based on key evaluation criteria

Scenario	C1	C2	C3	C4	C5
Scenario 1 – Basic Optimization	3	2	4	5	2
Scenario 2 – Cooperative Structure	4	5	3	3	3
Scenario 3 – Smart, Traceable Sector	5	3	3	2	5

1. Aggregated results

Final scores were calculated by multiplying each rating by its corresponding weight and summing the results:

2. **Scenario 1 – Basic optimization:** $(3 \times 0.30) + (2 \times 0.20) + (4 \times 0.20) + (5 \times 0.15) + (2 \times 0.15) = 3.15$

3. **Scenario 2 – Cooperative structure:** $(4 \times 0.30) + (5 \times 0.20) + (3 \times 0.20) + (3 \times 0.15) + (3 \times 0.15) = 3.70$

4. **Scenario 3 – Smart, traceable sector:** $(5 \times 0.30) + (3 \times 0.20) + (3 \times 0.20) + (2 \times 0.15) + (5 \times 0.15) = 3.75$

1. Final scenario ranking

Table (6) provides a comparative overview of three possible development paths for Algeria's sustainable sheep sector. Each scenario has been evaluated using multiple parameter (on a 5-point scale), reflecting its overall performance in terms of sustainability, efficiency, innovation, and practical feasibility.

1. Smart, traceable sector – Score: 3.75 / 5.00

Topping the list, this scenario focuses on updating the sector through digital technologies such as traceability systems, electronic identification, and enhanced veterinary management. The strong score suggests a clear preference for high-tech solutions that can bring more transparency, ensure product quality, and open doors to premium markets, especially

export and certified halal sectors. It aligns well with global trends like digitization and food safety, showing true potential to transform the sector in a meaningful way.

2. Cooperative structure – Score: 3.70 / 5.00

A close second, the cooperative model is seen as another strong strategy. It highlights the value of collective action among farmers, sharing resources, and improving governance. A well-structured cooperative could address several weaknesses identified in the earlier SWOT analysis, including a fragmented supply chain, limited access to mortgage, and absence of coordination. This approach builds on solidarity and could strengthen the sector

3. Basic optimization – Score: 3.15 / 5.00

Although this scenario receives a decent score, it lags behind the other two. It likely refers to conventional improvements, better feeding, reducing weaning losses, and supporting reproductive performance. While these steps are important, the strategy lacks the broader vision and transformative capacity of the other scenarios. It's a more conservative path, better suited as a foundation rather than a long-term solution.

In summary, the top-ranked options favor innovation and cooperation. This suggests that Algeria's sheep sector will need both smart tools and strong collective organization to truly move forward and become more competitive in today's evolving food systems.

Table 4. Ranking of development scenarios for a sustainable sheep sector in Algeria

Rank	Scenario	Total Score
1st	Smart, Traceable Sector	3.75 / 5.00
2nd	Cooperative Structure	3.70 / 5.00
3rd	Basic Optimization	3.15 / 5.00

1. **Toward an integrated strategy**

The scenarios are not mutually exclusive. On the contrary, the findings suggest that a blended strategy could produce the best outcomes:

1. Start with basic technical improvements (training, animal health, breeding).

2. Build cooperative networks to strengthen bargaining power, resource sharing, and access to processing.
3. Gradually integrate digital tools like traceability and certification to reach premium and export markets.

This phased approach aligns with local realities, available resources, and social expectations. It also reinforces each link in the value chain.

CONCLUSIONS

This study has analyzed the strengths and challenges of Algeria's sheep sector through a value chain perspective. Despite its cultural, social, and economic significance, the sector faces major obstacles, including weak organization, informal trade, and technical and environmental pressures.

To promote a sustainable transition, we propose the following operational recommendations:

1. Establish regional livestock platforms to coordinate stakeholders, facilitate knowledge exchange, and monitor sector performance.
2. Support cooperatives and producer associations through training, financial assistance, and market linkages to strengthen collective organization and bargaining power.
3. Invest in digital traceability systems to enhance transparency, product quality, and market access.

4. Upgrade veterinary and extension services to improve animal health, productivity, and resilience to environmental challenges.

5. Promote technical modernization and context-specific innovations, ensuring they align with local realities and resources.

Implementing these actions requires coordinated efforts from public authorities, private stakeholders, and local communities, supported by clear and consistent policies. Enhancing the sustainability of Algeria's sheep sector can strengthen food security, optimize natural resource use, and improve rural livelihoods. Future research should evaluate the long-term impact of these interventions and their adaptability across different regional contexts.

ACKNOWLEDGMENTS

This work was carried out within the framework of the National Research Project (PNR) entitled "Preservation of the Hamra Sheep Breed", focusing on the production of selected breeding rams and their dissemination among farmers in the breed's native regions (Saïda, Naâma, El Bayadh, and Tlemcen).

We express our deep gratitude to the People's Democratic Republic of Algeria for the funding and support provided for this project, which aims to preserve the national animal genetic heritage, promote sustainable livestock farming, and strengthen the capacities of farmers in the targeted regions.

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