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Research Article

Constrained intensification in Algerian Arid Zones: Systemic evaluation of agricultural development programs in Laghouat Province

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Abstract

Algerian agricultural development programs (Access to Agricultural Land Ownership - APFA and Land Development through Concession - MVTC) in arid regions aimed to expand agricultural production and create employment, but their economic efficiency remained poorly quantified. This study evaluated the economic performance and intensification modalities of agricultural development programs in the steppe zones of Laghouat province through a systemic analysis of farms. A stratified survey was conducted among 90 active farms distributed across three agroecological zones (Atlas Mountain Foothills, High Steppe Plains, Saharan Plateau). Data were analyzed using hierarchical cluster analysis, ANOVA, and discriminant analysis to identify production systems and evaluate their economic efficiency. Five distinct production systems emerged from the classificatory analysis: small diversified farms (9.2 ha, $5,065/year), mixed crop-livestock farms (31.4 ha, $16,900/year), large mechanized cereal farms (174 ha, $31,371/year), very small diversified farms (5.8 ha, $2,677/year), and arboricultural farms (1 ha, $708/year). The overall capital efficiency ratio was 1.84, with significant territorial variations ($F=3.58$, $p=0.032$). Quantitative expansion reached +78% of agricultural area, but qualitative intensification remained limited with yields often below national averages. The development programs generated marked differentiation of production systems according to local agroecological constraints. Decision-makers must adopt differentiated territorial approaches integrating agropastoral specificities to optimize the efficiency of public investments in arid zones.

Keywords: Agricultural development, Agricultural intensification, Economic efficiency, Steppe zones, Algeria

Introduction

Faced with the combined challenges of food security, climate change, and population growth, many countries have oriented their agricultural policies toward the valorization of marginal lands. In Algeria, where steppe and Saharan regions occupy more than 90% of the territory, ambitious agricultural development programs have been launched: Access to Agricultural Land Ownership (APFA) in 1983 and Land Development through Concession (MVTC) in 1997. These strategies responded to a triple constraint: exceptional population growth (>3% annually), deficient agricultural performance, and degradation of food self-sufficiency from 90% to 25% between 1969 and 1986 (Balta, 1991).

The 1983 APFA aimed at definitive privatization at a symbolic dinar with subsidized credits, while the 1997 MVTC proposed 40-year concessions with 70% public financing of infrastructure. Despite ambitious objectives, high abandonment rates occurred (37% for APFA, 80 to 98% for MVTC) according to Oubraham (2009) and ONTA (2024).

Despite considerable public investments and substantial land allocation, the economic efficiency of these interventions remains poorly documented. The literature reveals sectoral approaches and insufficient documentation of differentiated territorial effects (Côte, 1993, 2002; Bendjelid *et al.,* 2004; Bencherif, 2011; Daoudi *et al.,* 2015). These dynamics recall Mediterranean experiences: development programs in semi-arid Spain (Lasanta *et al.,* 2017) and constrained intensification in eastern Morocco (Mahdi, 2002). Unlike these extensive models, Algeria reveals unique differentiated intensification through systemic diversification.

Laghouat province represents an emblematic case: a bioclimatic transition zone from steppe to Sahara having benefited from more than 60,000 hectares allocated (78% of its current agricultural area), it presents agroecological diversity allowing analysis of differentiated policy effects according to territorial contexts (DSA, 2023).

This research evaluates the effectiveness of development programs in Laghouat province through territorial systemic analysis. The concept of differentiated constrained intensification, an adaptive process characterized by: 1) emergence of distinct specialized systems, 2) compensation through functional diversification, and 3) optimization according to local constraints.

The three complementary hypotheses tested were:

H1: Institutional asymmetry between technocratic design and local realities.

H2: Quantitative extension without measurable effective intensification.

H3: Differentiated effectiveness according to agroecological zones.

This research contributes theoretically by conceptualizing differentiated constrained intensification, a process distinct from adaptive extensification (Ellis & Swift, 1988) or sustainable intensification (Pretty, 1997). Unlike Mediterranean extensification models (Porqueddu *et al.,* 2016), our results reveal compensatory diversification maintaining productive objectives. The

systemic methodology produces an operational typology quantifying this differentiation.

Methods

Study area

Laghouat province, located at the junction of Algeria's steppe and Saharan zones, spans 25,052 km^2 and hosts a population of over 730,000 inhabitants. The territory is characterized by three distinct agroecological zones that structure our comparative analysis (Bouchattata & Moulai, 2018):

Atlas mountain piedmonts (AMP)

Representing 15.08% of the province's territory, characterized by a cold semi-arid climate with average precipitation of 350 to 400 mm/year and frost risks. Water potential is limited but overexploited.

High steppe plains (HSP)

Covering 18.54% of the territory, this flat relief zone presents a cool to cold semi-arid climate with precipitation between 200 and 300 mm/year. Water potential is greater with more balanced exploitation in certain municipalities.

Saharan plateau (SP)

Represents 66.38% of the territory, with an arid to pre-Saharan climate with limited precipitation (100 to 200 mm/year). It has significant underground water resources, but overexploited, particularly in the Laghouat municipality.

Sampling strategy

A two-level stratified sampling approach was adopted to capture the diversity of biophysical and socio-economic conditions:

Territorial stratification

The province was divided into three homogeneous agroecological zones. Within each zone, two representative municipalities in terms of the importance of agricultural area derived from development programs and the importance of sheep livestock. This approach resulted in the selection of Aflou and Oued Morra municipalities in the AMP zone, Sidi Makhlouf and Tadjmout municipalities in the HSP zone, and Laghouat and Bennacer Ben Chohra municipalities in the SP zone (Figure 1).

Sample size determination

Using the Bernoulli formula with a 95% confidence level and a 9.95% margin of error:

$$n = (p^2 \times N)/(p^2 + (2e)^2 \times (N-1))$$

Where: N=Parent population; e=Accepted margin of error; p=Proportion observed in the sample. The Bernoulli formula was chosen because it integrates three parameters justifying our selection: representativeness, sample homogeneity, and precision of collected data (Moulai & Bouammar, 2020).

This approach enabled the constitution of a representative sample of 90 active farms (80 APFA, 10 MVTC), reflecting the reality of high abandonment rates particularly for MVTC estimated between 80 to 98% (Oubraham, 2009; ONTA, 2024).

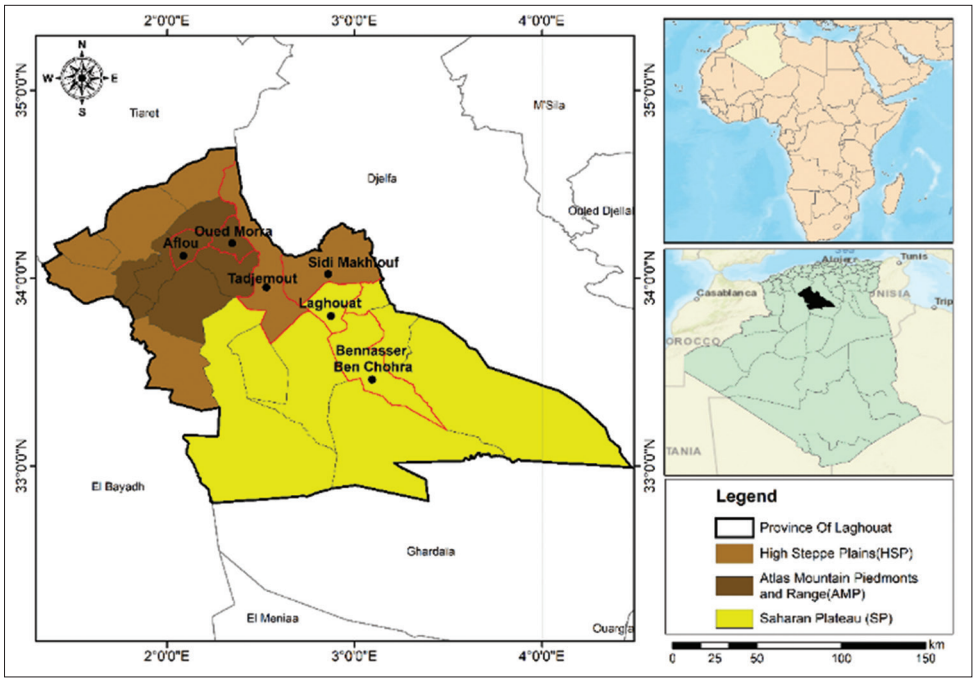

Figure 1: Location map of surveyed municipalities in Laghouat province according to the three agroecological zones
Source: Authors, 2025

Data collection

Face-to-face questionnaire surveys were conducted from June 2017 to October 2018. Data collection focused on structural variables (farm size, irrigated area, livestock numbers, mechanization level), economic variables (total investment, annual income, production costs, added value), technical variables (crop yields, cultivation practices, input use), and socio-demographic variables (farmer age, agricultural training, pluriactivity).

Complementary diachronic data

To address the limitations of the cross-sectional survey approach (2017-2018), the present study integrated data from a territorial agrarian diagnosis conducted in 2023 covering the period 1990-2023. This retrospective approach, based on documentary analysis (DSA, MADR data), interviews with resource persons (retired officials, experienced farmers), and exploitation of long statistical series, allows contextualization of identified typologies in an evolutionary perspective and validation of the stability of observed production systems.

Statistical analysis

Hierarchical cluster analysis (HCA)

Ward method on 7 standardized variables (agricultural area, income, livestock, mechanization, water flow, crop distribution). Optimal number of clusters (k=5) determined by silhouette analysis.

Validation

ANOVA for between-cluster comparisons, non-parametric tests (Kruskal-Wallis), chi-square and discriminant analysis. Bonferroni post-hoc corrections applied.

Efficiency indicators

Capital efficiency ratio: Net Added Value/Total Investment

Land productivity: Agricultural income/hectare

Factor productivity: Income/AWU (Agricultural Work Unit)

These indicators draw from the agricultural systems sustainability assessment framework (Schader *et al.,* 2014) by favoring a multi-criteria approach adapted to arid zone constraints. The emphasis on capital efficiency reflects the specificities of extensive systems where investment optimization takes precedence over input intensification (Tittonell, 2020).

Analyses were performed using SPSS 26, with normality tests (*Shapiro-Wilk*) and homogeneity of variances (*Levene*) conducted.

Results

Farm typology and agricultural production systems

Farm classification

Hierarchical cluster analysis identified five distinct production systems (silhouette score 0.293; significant differences in agricultural area and income, $p<0.001$).

Cluster 1 (small diversified farms, 55.6%) presents 9.2 ha, 64 sheep heads, efficiency ratio 1.46. Cluster 2 (mixed crop-livestock, 20.0%) extends over 31.4 ha, 126 sheep heads, ratio 1.40. Cluster 3 (large cereal farms, 2.2%) covers 174 ha, generates maximum income ($31,371/year) with a ratio of 1.60. Cluster 4 (very small diversified, 21.1%) of 5.8 ha displays the best ratio (1.98). Cluster 5 (arboricultural, 1.1%) of 1 ha presents the lowest ratio (0.61). Figure 2 presents a radar chart comparing the main technical and structural characteristics of each cluster, illustrating the diversity of productive profiles identified.

Territorial economic performance

Average agricultural income per farm stands at $7,464/year, with significant variability (-$145 to $2,685/ha). The overall capital efficiency ratio reaches 1.84. Analysis of variance reveals highly significant differences between agroecological zones for agricultural income ($F=9.19$, $p=0.0002$), agricultural area classes ($F=35.72$, $p<0.0001$), and capital efficiency ($F=3.58$, $p=0.032$). Territorial contrasts are marked.

The AMP zone presents an average agricultural area of 35.9 ha, the highest efficiency ratio (4.87) but the lowest investment intensity (245.38 $/ha). The HSP zone displays an average agricultural area of 6.8 ha, an intermediate efficiency ratio (1.57) but the highest investment intensity (460.70 $/ha). The SP zone presents an intermediate value for agricultural area, the lowest efficiency ratio (0.84), and moderate investment intensity (364.73 $/ha). Investment intensity shows significant differences between

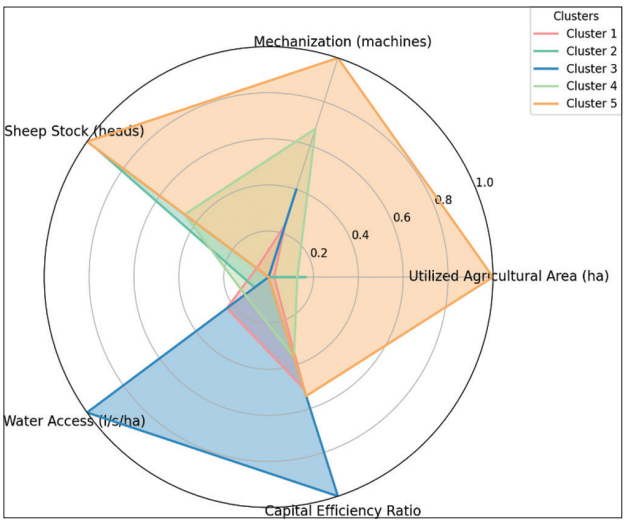

Figure 2: Technical and structural profiles of farm clusters

agroecological zones ($F(2,87)=3.58$, $p=0.032$, $\eta^2=0.82$), confirming the influence of location on investment strategies. Figure 3 presents a comparative synthesis of main economic performance indicators according to agroecological zones.

Productive and technical dynamics

Agricultural expansion and intensification

Development programs enabled an expansion of +78% of agricultural area and a 5.3-fold multiplication of irrigated surfaces (DSA, 2023).

Observed yields show variable performance compared to national averages (MADR, 2019). Superior productions concern durum wheat (26.72 vs 21.3 quintals/ha) and date palm (120 vs 68.8 quintals/ha). Lower yields affect barley (15.29 vs 18.1 quintals/ha), potato (146 vs 310 quintals/ha), and particularly alfalfa (200 vs 1,080 bales/ha).

Evolutionary trajectories and diachronic validation (1990-2023)

Retrospective analysis reveals three distinct phases. The establishment phase (1990-2005) generated an expansion of +57.4%. The maturation phase (2005-2015) saw the emergence of large mechanized farms. The stabilization phase (2015-2023) confirms the persistence of 78% of farms in their original system. Table 1 presents the main evolution indicators by agroecological zone (1990-2023).

This validation demonstrates that our typologies correspond to sustainable structural equilibria rather than transitory states.

Cultural practices and agropastoral integration

Analysis reveals a dominant five-year rotation system: Wheat - Wheat - Barley (years n to n+2), followed by market garden crops (year n+3), then fallow or legumes. Practices vary according to agroecological zones. Mineral fertilization concerns 52.4% of farms, with 40% in AMP zone versus 50% in HSP and SP zones. Irrigation affects 82.6% of cereals, with territorial disparities: 98% in SP zone, 90% in HSP zone, and 57.14% in AMP zone. Agriculture-livestock integration manifests through stubble grazing after harvest and intensive alfalfa cultivation (6 to 8 annual cuts). Extensive practices persist: 57.5% of farmers do not practice weeding and 90.2% abstain from phytosanitary treatments. Figure 4 presents the technical practices adopted in cereal production according to the three agroecological zones.

Socio-economic impacts and determinants

Employment and income distribution

Farms generate on average 4.31 Annual Work Units (AWU) per farm, varying from 10 AWU (large cereal farms) to 1.5 AWU (arboricultural). Territorial distribution reveals marked differences with 6.75 AWU on average in AMP zone (standard deviation 2.75), 4.05 AWU in SP zone (standard deviation 1.98), and 3.49 AWU in HSP zone (standard deviation 1.64).

Employment structure is distributed between family labor (51.3%), employees (34.3%), and seasonal workers (14.4%). However, job quality remains problematic with 270 days/year of work, average remuneration of $122/month, below the National Minimum Guaranteed Wage (NMGW) of $155/month, and 94% of jobs without formal contracts or social coverage.

Average farmer income stands at $7,915/year with 30.6% of farms generating income below the NMGW, while 69.4% exceed this minimum threshold.

Investment structure and economic determinants

Investment distribution reveals concentration on water resources (42.7%), agricultural equipment (28.3%), and arboricultural plantations (10.5%). Financing relies on

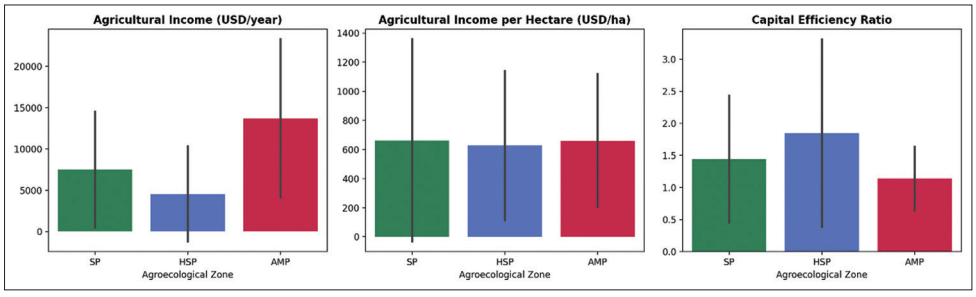

Figure 3: Economic performance indicators by agroecological zone (USD)

Table 1: Evolution indicators by agroecological zone (1990-2023)

Indicators	AMP	HSP	PS	Province average
ΔUAA (%)	+78,3	+45,2	+67,1	+57,4
Δ Wheat yield (quintals/ha)	15→26	11→21	12→24	12→23,7
Δ Irrigated UAA (%)	+45,8	+67,3	+156,2	+89,7
Dominant evolution	Intensive market gardening	Cereal-livestock	Integrated diversification	Differentiated intensification

Source: Authors' synthesis based on territorial agrarian diagnosis (2023), DSA Laghouat data (1990-2023) and MADR (2000-2022)

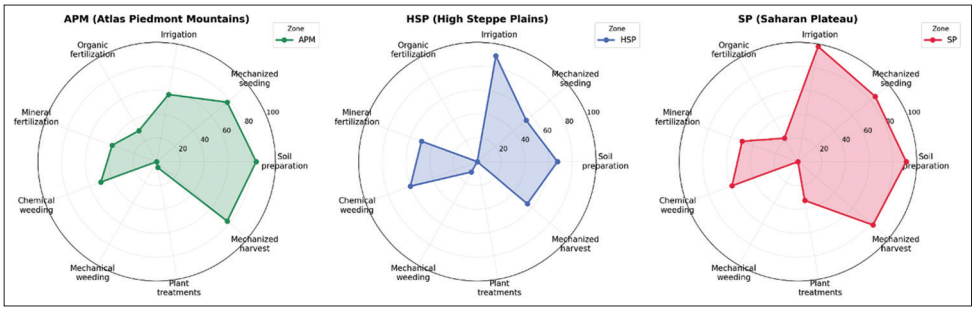

Figure 4: Technical practices in cereal production across agroecological zones

state subsidies (60.0%) and self-financing (30.7%), with bank loans representing only 9.3%. Regression analysis reveals that total Net Added Value is determined by animal and plant production NAV (β=0.913, p<0.001). Territorial variations show that AMP zone presents the highest investments ($6,930) with the best efficiency ratio (4.88), while SP zone displays the lowest ratio (0.84). Territorial performance variations reveal significant contrasts between agroecological zones. AMP zone presents the highest investments ($6,930 per farm) with the best efficiency ratio (4.88). HSP zone displays moderate investments ($2,632) with an intermediate ratio (1.57). SP zone shows average investments ($4,196) but the lowest efficiency ratio (0.84). ANOVA confirms these significant differences between zones for investment levels ($F(2,87)=3.58$, $p = 0.032$, $\eta^2=0.82$).

Discussion

Validation of differentiated constrained intensification in arid zones (H1 and H2)

This dynamic reveal differentiated constrained intensification, distinct from classical adaptive extensification (Tittonell, 2020) through three characteristics: 1) maintenance of productive objectives despite constraints, 2) compensatory systemic diversification rather than simple input reduction, 3) emergence of distinct specialized systems (ratios 0.61 to 1.98) versus traditional extensive homogenization. The concept of differentiated constrained intensification is proposed here, defined as a productive adaptation process characterized by: 1) emergence of distinct specialized systems, 2) compensation for the impossibility of vertical intensification through functional diversification, and 3) optimization according to specific constraints of each context.

The retrospective analysis 1990-2023 validates this dynamic through identification of three evolutionary phases (establishment, maturation, stabilization). The persistence of 78% of farms in their original system over 2010-2023 confirms that this differentiation represents sustainable equilibria facing arid constraints, not temporary transitions.

This concept differs from classical Boserupian intensification (Boserup, 1965) through systemic diversification replacing technical convergence and adaptation to constraints taking precedence over maximum productivity. Unlike deliberate agroecological transitions (Moraine *et al.,* 2014), differentiated constrained intensification emerges as a forced response to biophysical and institutional limitations. This distinction is crucial for understanding adaptation dynamics in marginal zones. Classical intensification theories (Jacquet & Flichman, 1988) thus prove insufficient to explain these adaptive dynamics in arid zones.

Analysis of differentiated economic performances contradicts neo-institutional postulates (Coase, 1960; Demsetz, 1967) which assume that privatization uniformly stimulates investment. Our results align with Hadeid (2011) and Ben Hounet (2013) on APFA law application in Algerian steppe environments, revealing that private property rights efficiency depends on local socio-economic and agroecological context.

Despite differentiated territorial contexts, the results reveal adaptive convergence where systems tend toward similar efficiency levels. This convergence is explained by the problematic articulation between formal and informal institutions (North, 1990), generating uniform structural constraints.

Territorial differentiation and centrality of agropastoral livestock (H3)

Hypothesis H3 finds validation in efficiency gaps between agroecological zones: 4.87 in AMP versus 0.84 in SP ($F=3.58$, $p=0.032$), confirming that program effectiveness depends on local biophysical and socio-economic conditions, aligning with Mediterranean studies (Gamoun *et al.,* 2012; Porqueddu *et al.,* 2016).

Our results reaffirm the structuring centrality of livestock in all steppe systems. With β=0.913 (p<0.001) and r=0.90 between animal NAV and total NAV, livestock determines overall economic performance, surpassing plant production (r=0.80). This quantified confirmation of works by Bencherif (2011) and Moulai and Bouammar (2015) brings robust empirical dimension to previous qualitative observations, converging with studies on mixed crop-livestock systems that demonstrate their superiority in terms of resilience and resource efficiency (Ryschawy *et al.,* 2012; Dumont *et al.,* 2013).

This centrality manifests particularly in mixed crop-livestock systems ($16,900/year with 126 sheep heads) and small diversified farms (64 sheep heads

contributing to $5,065/year). Unlike temperate models where livestock adapts to crops, sheep farming determines overall performance, aligning with recommendations by Kanoun *et al.* (2007) and Bencherif (2011). This paradigmatic inversion underlines that in arid and semi-arid environments, livestock does not constitute a simple complement to agriculture, but rather the economic pillar around which other productive activities are organized, confirming the necessity of designing agricultural policies centered on pastoral system optimization rather than their marginalization.

Job creation reveals variable performance according to systems (10 AWU for large farms vs 1.5 AWU for arboricultural) and confirms territorial influence (6.75 AWU in AMP vs 3.49 in HSP). However, quality and sustainability of agricultural jobs remain problematic with 94% of jobs without formal contracts and average remuneration ($122/month) below NMGW, aligning with critical analyses by Baroud *et al.* (2018) on social limits of agricultural development.

Financing analysis reveals massive dependence on public subsidies (60%) which questions allocative efficiency of resources, coupled with quasi-failure of institutional bank credit (9.3% utilization) despite subsidy schemes. This failure results from a double constraint: religious barriers (73.3% of farmers) and variable investment intensity (245.38 $/ha in AMP vs 460.70 $/ha in HSP) which testifies to adaptation to local constraints without productive efficiency optimization. These findings converge with works by Oubraham *et al.* (2021) which confirm the impact of religious motives in non-recourse to credit, even facing fully subsidized credit (Ettahadi at 0% interest). The study also reveals that bank-farmer information asymmetry and rationing strategies adopted by banks (personal contribution requirements, fairly short repayment periods, etc.) constitute structural barriers that massively exclude applicants, thus enriching analyses by Daoudi *et al.* (2015) on agricultural financing failures in Algeria.

Our finding of differentiated efficiency (0.61 to 1.98) provides empirical quantification to previous qualitative analyses, converging with Baroud *et al.* (2018) on development problems despite granting property rights. This measure validates the hypothesis of asymmetry between technocratic design and local realities formulated by Daoudi *et al.* (2015), enriching the debate on ecological intensification adapted to arid zones.

Implications for rural development policies and perspectives

Performance heterogeneity calls for paradigmatic renewal along three priority axes:

Differentiation of interventions

Variability in efficiency ratios (1.98 vs 0.61) requires adapting support mechanisms to specificities of each system, favoring technical support for very small farms and capital/production optimization for large ones.

Strengthening integrated agropastoral approach

Livestock centrality (β=0.913, r=0.90) requires integrating the pastoral dimension as a structuring element, not complement, empirically validating recommendations by Bourbouze (2002), Kanoun *et al.* (2007) and Bencherif (2011).

Territorialized financial innovation

Religious barriers (73.3%) and differential efficiency between zones (4.87 in AMP vs 0.84 in SP) call for adapted financial instruments (development of financial instruments adapted to religious convictions, improvement of banking procedures and establishment of mutual guarantee systems to reconcile convictions and financing needs) and policy territorialization.

Our research presents three main limitations: absence of longitudinal data limits analysis of evolutionary trajectories (Daoudi *et al.,* 2021); selection bias excluding failures; single-province scale limits generalization, calling for inter-regional comparative research (Otmane & Kouzmine, 2013).

Research perspectives

Five directions emerge to extend this research. First, longitudinal analyses (15-20 years) would allow grasping adaptation cycles and validating supposed causal mechanisms. Second, inter-regional comparative research integrating steppe and Saharan specificities would enrich results generalization. Third, applying the MESMIS framework (López-Ridaura *et al.,* 2002) and multi-criteria evaluation approaches (Schader *et al.,* 2014) would enable more holistic sustainability assessment of identified systems. Fourth, integrating participatory approaches (Darnhofer *et al.,* 2016) would valorize local knowledge in intensification trajectory analysis. Finally, incorporating new dimensions (gender, ecosystem services, climate prospective) is imperative for a systemic approach to agrarian transformations in arid zones.

This research fundamentally contributes to theoretical debate by demonstrating that development policy effectiveness in arid zones lies less in practice uniformization than in recognition and support of adaptive diversity of agropastoral systems. Facing climate change challenges, this analysis establishes that sustainable transformation of marginal lands requires a holistic approach valorizing local specificities, sine qua non condition for resilient development of Algerian steppe territories.

Conclusions

This systemic evaluation of agricultural development policies in Laghouat province reveals complex and differentiated transformations that redefine our understanding of development dynamics in arid zones. Typological analysis identifies five distinct production systems characterized by remarkably variable economic efficiency levels, with ratios

ranging from 0.61 for specialized arboricultural farms to 1.98 for very small diversified farms.

Our results largely confirm our research hypotheses. The institutional asymmetry between technocratic design and local realities finds robust empirical validation in the persistence of extensive practices and yield gaps. Quantitative extension without proportional intensification is confirmed by 78% expansion of UAA coupled with a modest overall efficiency ratio of 1.84. Territorial differentiation manifests through efficiency gaps between agroecological zones, with ratios of 4.87 in AMP zone versus 0.84 in SP zone ($F=3.58$, $p=0.032$).

This research enriches the theoretical corpus by proposing the concept of differentiated constrained intensification. Unlike classical models, our results demonstrate that adaptation to arid constraints generates diversification of production systems rather than convergence toward a single model, revealing that sustainability passes through adaptive diversity.

Analysis of determinants reveals the structuring centrality of livestock in all production systems. With a regression coefficient $\beta=0.913$ ($p<0.001$) and correlation $r=0.90$ between animal NAV and total NAV, livestock determines overall economic performance, inverting the traditional paradigm and demonstrating that agricultural development policies in arid zones must integrate the pastoral dimension as a structuring element.

The heterogeneity of identified systems, from small farms to large farms, reveals divergent trajectories that call for redesigning public intervention instruments. The coexistence of efficiency ratios varying by a factor of three demonstrates that policy effectiveness depends on their capacity to adapt to production system specificities.

Despite considerable public investments (60% of financing), economic efficiency remains modest, questioning the sustainability of the promoted model. Job creation, although significant with 4.31 AWU per farm, remains fragile with 94% of jobs without formal contracts.

Policy implications call for paradigmatic renewal of rural development approaches. Performance variability requires fine differentiation of public interventions toward adaptive policies integrating the agropastoral approach and innovating in financial instruments adapted to local sociocultural contexts.

This research contributes to theoretical debate by providing empirical quantification of economic efficiency and territorial differentiation of agricultural development programs in arid zones. The orig/inal contribution lies in the systemic methodology producing an operational typology of production systems. This research also fits within the global movement of recognizing ecological intensification as the path forward for Southern agricultures (Wezel *et al.,* 2020). The differentiated constrained intensification identified in Algerian steppes illustrates the innovation capacities of agropastoral systems facing constraints, aligning with analyses on family system resilience (Darnhofer *et al.,* 2016).

Facing climate change challenges, this analysis demonstrates that policy effectiveness lies in recognition and support of adaptive diversity of agropastoral systems, sine qua non condition for resilient development of Algerian steppe territories.

Author contributions

Adel Moulai - Conceptualization, Methodology, Field surveys, Data collection, Formal analysis, Results interpretation, Writing - original draft. Boualem Bouammar - Supervision, Methodological guidance, Analytical framework, Review and Validation. All authors approved the final manuscript.

References

Balta, P. (1991). Double défi pour l'Algérie [A double challenge for Algeria]. *Revue des deux mondes,* 78-91.

Baroud, K., Colin, J.-P., & Daoudi, A. (2018). La politique d'accès à la propriété privée des terres mises en valeur en zones arides en Algérie. Éléments de discussion [The policy of access to private ownership of developed land in arid zones in Algeria. Points for discussion]. *Économie rurale, 363*, 81-98. https://doi.org/10.4000/economierurale.5423

Ben Hounet, Y. (2013). Propriété, appropriation foncière et pratiques du droit en milieu steppique (Algérie) [Property, land appropriation and legal practices in a steppe environment (Algeria)]. *Études rurales, 192*, 93-115.

Bencherif, A. (2011). La sécurité alimentaire en Algérie: enjeux et perspectives [Food security in Algeria: challenges and prospects]. *Cahiers Options Méditerranéennes, 95*, 171-186.

Bendjelid, A., Brûlé, J.-C., & Fontaine, J. (2004). *Aménageurs et aménagés en Algérie: Héritages des années Boumediene et Chadli [Planners and those who are planned in Algeria: Legacies of the Boumediene and Chadli years]*. L'Harmattan.

Boserup, E. (1965). *The conditions of agricultural growth: The economics of agrarian change under population pressure*. Routledge.

Bouchattata, T., & Moulai, A. (2018). *Diagnostic participatif territorial dans la wilaya de Laghouat [Participatory territorial diagnosis in the wilaya of Laghouat]* (Rapport technique Projet PAP-ENPARD).

Bourbouze, A. (2002). Les temps longs du développement: patientes transformations des systèmes d'élevage au Maghreb [The long timescales of development: patient transformations of livestock systems in the Maghreb]. In Dans M. Dufumier (Ed.), *Un agronome dans son siècle [An agronomist of his century]* (pp. 95-107). Karthala.

Coase, R. H. (1960). The problem of social cost. *Journal of Law and Economics, 3*, 1-44.

Côte, M. (1993). Essors et menaces sur le Sahara. Mise en valeur: Les réformes récentes de mise en valeur agricole [Growth and threats to the Sahara. Development: Recent agricultural development reforms]. *Les Cahiers d'URBAMA, 8*, 11-27.

Côte, M. (2002). Des oasis aux zones de mise en valeur: l'étonnant renouveau de l'agriculture saharienne [From oases to development zones: The astonishing revival of Saharan agriculture]. *Méditerranée, 98*(1-2), 5-12.

Daoudi, A., Colin, J. P., & Baroud, K. (2021). La politique de mise en valeur des terres arides en Algérie: une lecture en termes d'équité [The policy for developing arid lands in Algeria: An analysis in terms of equity]. *Cahiers Agricultures, 30*, 4.

https://doi.org/10.1051/cagri/2020038

Daoudi, A., Colin, J.-P., Derderi, A., & Ouendeno, M. L. (2015). Mise en valeur agricole et accès à la propriété foncière en steppe et au Sahara (Algérie) [Agricultural development and access to land ownership in the steppe and the Sahara (Algeria)]. *Les Cahiers du Pôle Foncier, 8*, 1-28.

Daoudi, A., Terranti, S., Hammouda, R. F., & Bédrani, S. (2013). Adaptation à la sécheresse en steppe algérienne: le cas des stratégies productives des agropasteurs de Hadj Mechri [Adapting to drought in the Algerian steppe: the case of production strategies of Hadj Mechri's agropastoralists]. *Cahiers Agricultures, 22*(4), 303-310. https://doi.org/10.1684/agr.2013.0629

Darnhofer, I., Lamine, C., Strauss, A., & Navarrete, M. (2016). The resilience of family farms: Towards a relational approach. *Journal of Rural Studies, 44*, 111-122. https://doi.org/10.1016/j.jrurstud.2016.01.013

Demsetz, H. (1967). Toward a theory of property rights. *The American Economic Review, 57*(2), 347-359.

DSA. (2023). *Données du secteur agricole [Agricultural sector data]*. Direction des Service Agricole.

Dumont, B., Fortun-Lamothe, L., Jouven, M., Thomas, M., & Tichit, M. (2013). Prospects from agroecology and industrial ecology for animal production in the 21st century. *Animal, 7*(6), 1028-1043. https://doi.org/10.1017/S1751731112002418

Ellis, J. E., & Swift, D. M. (1988). Stability of African pastoral ecosystems: Alternate paradigms and implications for development. *Journal of Range Management, 41*(6), 450-459. https://doi.org/10.2307/3899515

Gamoun, M., Louhaichi, M., Ben Salem, F., Gouhis, F., & Ouled Belgacem, A. (2012). *Rangeland management in southern Tunisia: Rest strategies for sustaining rangeland productivity*. ICARDA.

Hadeid, M. (2011). La politique de mise en valeur agricole en milieu steppique algérien: un essai de bilan dans les Hautes Plaines sud oranaises (Algérie) [Agricultural development policy in the Algerian steppe: A preliminary assessment in the Southern Oranese High Plains (Algeria)]. *Insaniyat, 51-52*, 99-118. https://doi.org/10.4000/insaniyat.12723

Jacquet, F., & Flichman, G. (1988). Intensification et efficacité en agriculture [Intensification and efficiency in agriculture]. *Économie Rurale, 183*, 49-54. https://doi.org/10.3406/ecoru.1988.3879

Kanoun, A., Kanoun, M., Yakhlef, H., Cherfaoui, Z., & Abdelali Martini, M. (2007). Pastoralisme en Algérie: systèmes d'élevage et stratégies d'adaptation des éleveurs ovins [Pastoralism in Algeria: Livestock systems and adaptation strategies of sheep farmers]. *14èmes Rencontres Recherches Ruminants* (pp. 435-438). Institut de l'Élevage.

Lasanta, T., Errea, M. P., & Nadal-Romero, E. (2017). Traditional agrarian landscape in the Mediterranean mountains: A regional and local factor analysis in the Central Spanish Pyrenees. *Land Degradation & Development, 28*(5), 1626-1640. https://doi.org/10.1002/ldr.2695

López-Ridaura, S., Masera, O., & Astier, M. (2002). Evaluating the sustainability of complex socio-environmental systems. The MESMIS framework. *Ecological Indicators, 2*(1-2), 135-148. https://doi.org/10.1016/S1470-160X(02)00043-2

MADR. (2019). *Statistique agricole. Série B [Agricultural Statistics. Series B]*. Ministère de l'Agriculture et du Développement Rural.

Mahdi, M. (2002). Du nomadisme aux nouvelles formes d'élevage [From nomadism to new forms of livestock farming]. In M. Mahdi (Ed.), Mutation sociale et réorganisation des espaces steppiques [Social transformation and the reorganization of steppe landscapes] (pp. 65-90). Konrad Adenauer.

Moraine, M., Duru, M., Nicholas, P., Leterme, P., & Therond, O. (2014). Farming system design for innovative crop-livestock integration in Europe. *Animal, 8*(8), 1204-1217. https://doi.org/10.1017/S1751731114001189

Moulai, A., & Bouammar, B. (2015). Intérêts et enjeux autour de la privatisation du foncier steppique: cas des M'khalif de Bennana [Interests and stakes surrounding the privatization of steppe land: The case of the M'khalif of Bennana]. In Dans G. Vianey, M. Requier-Desjardins & J. C. Paoli (Eds.), *Accaparement, action publique, stratégies individuelles et ressources naturelles: regards croisés sur la course aux terres et à l'eau en contextes méditerranéens [Land grabbing, public action, individual strategies, and natural resources: Intersecting Perspectives on the race for land and water in mediterranean contexts]* (pp. 229-247). CIHEAM.

Moulai, A., & Bouammar, B. (2020). La problématique de la politique d'accession à la propriété foncière agricole dans la wilaya de Laghouat [The problem of the policy of access to agricultural land ownership in the Wilaya of Laghouat]. *El-Bahith Review*, *20*(1), 237-252.

North, D. C. (1990). *Institutions, institutional change and economic performance*. Cambridge University Press. https://doi.org/10.1017/CBO9780511808678

ONTA. (2024). *Situation du foncier agricole dans la wilaya de Laghouat* [The state of agricultural land in the Wilaya of Laghouat]. National Office for Agricultural Lands.

Otmane, T., & Kouzmine, Y. (2013). Bilan spatialisé de la mise en valeur agricole au Sahara algérien. *Cybergeo: European Journal of Geography, 632*. https://doi.org/10.4000/cybergeo.25732

Oubraham, F. (2009). *Essai d'évaluation ex-post de l'expérience de la mise en valeur des terres par la concession dans la wilaya de Laghouat* [Ex-Post evaluation study of the land development experience through concession in the Wilaya of Laghouat]. Master's Thesis, National School of Agronomy.

Oubraham, F., Bédrani, S., & Belhouadjeb, F. A. (2021). La bonification du crédit favorise-t-elle vraiment le financement des exploitations agricoles ? Cas de la wilaya de Laghouat en Algérie [Does interest rate subsidy really promote the financing of farms? The case of the wilaya of Laghouat in Algeria]. *Cahiers Agricultures, 30*, 23. https://doi.org/10.1051/cagri/2021008

Porqueddu, C., Ates, S., Louhaichi, M., Kyriazopoulos, A. P., Moreno, G., del Pozo, A., Ovalle, C., Ewing, M. A., & Nichols, P. G. H. (2016). Grasslands in 'Old World' and 'New World' Mediterranean-climate zones: Past trends, current status and future research priorities. *Grass and Forage Science, 71*(1), 1-35. https://doi.org/10.1111/gfs.12212

Pretty, J. N. (1997). The sustainable intensification of agriculture. *Natural Resources Forum, 21*(4), 247-256. https://doi.org/10.1111/j.1477-8947.1997.tb00699.x

Ryschawy, J., Choisis, N., Choisis, J. P., Joannon, A., & Gibon, A. (2012). Mixed crop-livestock systems: an economic and environmental-friendly way of farming? *Animal, 6*(10), 1722-1730. https://doi.org/10.1017/S1751731112000675

Schader, C., Grenz, J., Meier, M. S., & Stolze, M. (2014). Scope and precision of sustainability assessment approaches to food systems. *Ecology and Society, 19*(3), 42. https://doi.org/10.5751/ES-06866-190342

Tittonell, P. (2020). Assessing resilience and adaptability in agroecological transitions. *Agricultural Systems, 184*, 102862. https://doi.org/10.1016/j.agsy.2020.102862

Wezel, A., Herren, B. G., Kerr, R. B., Barrios, E., Gonçalves, A. L. R., & Sinclair, F. (2020). Agroecological principles and elements and their implications for transitioning to sustainable food systems. A review. *Agronomy for Sustainable Development, 40*, 40. https://doi.org/10.1007/s13593-020-00646-z