Research Article

A Statistical Approach to Understanding Agricultural Dynamics of the Béni Abbès Oasis in Southwest Algeria

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Abstract | This study examines the socio-agricultural dynamics of the Béni Abbès oasis in Southwest Algeria. We employed information from 30 experienced farmers to conduct Multiple Correspondence Analysis (MCA) and skewness analysis, clarifying the relationships among agricultural measures. These indicators function as quantitative variables that denote critical attributes, including educational attainment, agricultural experience, training, fertilizer application, pesticide utilization, water management, and perceptions of climate change. By employing mathematical modeling of these variables, we built conceptual connections that demonstrate their combined impact on agricultural sustainability. Skewness analysis was utilized to evaluate the asymmetry of the distribution of these variable functions. A positive skewness indicates that the majority of observations are concentrated around lower values, accompanied by a few high outliers. In contrast, a negative skewness reflects a larger prevalence of elevated values. The utilization of fertilizers and training demonstrated positively skewed distributions, signifying limited access at higher levels. The agricultural experience demonstrated negative skewness, signifying a preponderance of older, highly experienced farmers and a dearth of younger successors. This research clarifies the impact of traditional knowledge and modern forces on farming practices in the Oasis. The research encompassed histogram-based data distributions for several essential characteristics, including education level, training, and traditional agricultural techniques. These visualizations highlighted the dominance of informal knowledge exchange and the limited scope of official agriculture education. Farmers in Béni Abbes face considerable obstacles, including climate change, desertification, water overexploitation, limited access to modern equipment, and little institutional support. Our research indicates that 90% of farmers associate climate change with reduced productivity and soil desiccation, while 75% contend that sand encroachment significantly intensifies land degradation. Furthermore, inadequate financial resources and little agricultural guidance persist as ongoing challenges. Proposed solutions include the implementation of efficient irrigation systems, enhancing agricultural education, integrating youth into modern farming practices, and strengthening collaboration among farmers. Combining traditional practices with modern tactics is essential for ensuring a resilient and sustainable agricultural future in arid regions like Béni Abbes.

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Introduction

With more than 80% of Algeria's surface area being covered by the Sahara Desert, the challenges of environmental conditions are enormous. The Sahara is a huge desert that spans approximately 1,500 km from the Saharan Atlas to the edges of Niger and Mali meeting the dry sub-tropical and tropical climates (Bouraiou *et al*., 2018). The oases found in this part of the world, such as Béni Abbes, depend on underground water resources, including both the continental intermediary and terminal complex aquifers, brought by innovative water management systems such as foggaras. These oases are crucial biodiversity conservation centers that sustain a variety of flora and fauna as well as provide necessary ecosystem services (Aouar and Bachir, 2019; Merzougui *et al*., 2019).

The history of how humans have adapted to the Algerian Sahara illustrates humanity's ability to turn even the most unfavorable terrain into agricultural breadbaskets with generations of accumulated wisdom and innovation (Malvar *et al*., 2019; Teixidor-Toneu *et al*., 2022). Native populations have developed sophisticated techniques for farming native ecosystems. Their ostrich-farming system, involving the agro-silver-pastoral mixed-cropping model relating to the date palm, represents an innovative hybrid model that aims to pursue both environmental sustainability and agricultural efficacy (Bensaha *et al*., 2023).

Agriculture is an important sector for the economy of Algeria, producing a large share of the gross domestic product and employing a significant share of the population. Today, the Béni Abbes oasis confronts the challenges of global warming and water scarcity and attempts to balance old customs and modern agricultural systems(Boualem *et al*., 2017; Pappinen *et al*., 2020). Those problems are similar to those that are present in the conditions of agriculture in other dry regions, for example, in many agricultural lands located in Pakistan (Lashari *et al*., 2022). The socio-agricultural dynamics in Béni Abbes may provide a useful parable to broader South Asian conditions (Djoudi *et al*., 2024).

This research sheds light on the social and agricultural situation of the Béni Abbes area as well as a series of problems that farmers are experiencing with some suggestions on how to relieve their hardships (Hadj *et al*., 2022). We provide a conceptual framework to connect agricultural variables via mathematical formulation and capture the qualitative relationships among the observed variables and trends. Moreover, we use statistical analysis to determine how the agricultural variables are distributed via the skewness scale, which enriches the understanding of agriculture in Béni Abbes.

Materials and Methods

Béni Abbes, southwestern Algeria, gained the status of an autonomous province by virtue of the newly passed Law 19-12, dated 11/12/2019 (see Figure 1). It extends over an area of 112,000 km^2 and has a population of some 60,000, covering six districts and ten communes. It was part of the former Bechar Province, Located at National Road N°6, 241 km south of Bechar and 1,200 km southwest of Algiers and is one of the major centers in Saoura. Béni Abbes is between Bechar (north) and Timimoun and Adrar (south). It is referred to as the "Pearl of the Saoura" or also the "White Oasis" as it is situated among 28 other oases that border the town and is very important for the economic life of the region. In addition, it has a unique location between the dunes of the Grand Erg Occidental and Saoura Valley to enhance its natural beauty and support socio-economic activities. Béni Abbes became increasingly important as a southern Algeria regional center given its agricultural and oasis-based economy and its location on an important national road (Klingel *et al*., 2015; Metri *et al*., 2017; Remini *et al*., 2020).

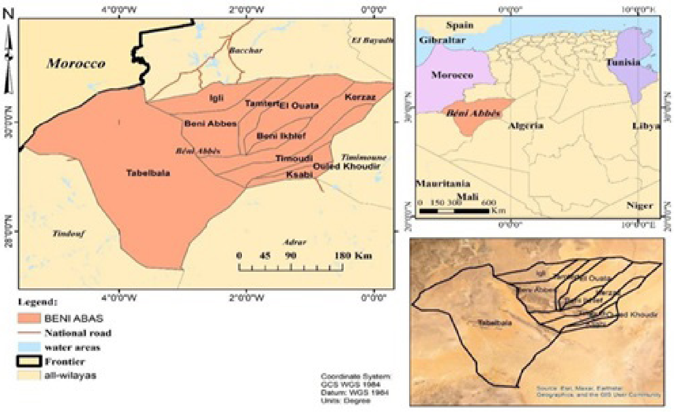

Figure 1: *The location map of the Béni Abbes region.*

Study and discuss field investigation

A comprehensive field survey was carried out to obtain the necessary data on agricultural output in

Béni Abbes. It involved one-on-one discussions with officials in agriculture and veteran farmers. A group of 30 farmers from the Béni Abbes oasis was chosen as the sample for this study. Selection criteria were targeted at individuals who were locally known to have long-term, extensive experience as a farmer with a strong understanding of oasis farming (more than 20 years of practical farming in the oasis). Although no fully random sampling frame was available for all farmers, diversity was addressed within this group of experienced farmers by targeting farmers in various parts of the oasis that were found through local extension services. The purposeful sampling of participants allowed maximum variation and context-specific forms of understanding of the practices and difficulties established quantitative and qualitative information related to the features of agricultural practices, farming challenges, and perspectives on production practices will be obtained through this study. We also wanted to have both sides of the story in Béni Abbes speak directly to officials and farmers.

Table 1: *Percentage of farmers distribution according to experience.*

Education level			Agricultural training		The family farm	
Illiter-acy	Primary school	High school	Yes	No	Yes	No
33,30%	30%	36,70%	90%	10%	95%	5%

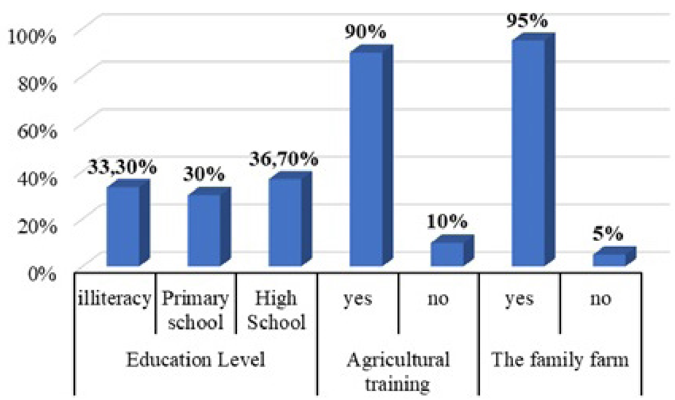

Figure 2: *Percentage of farmers distribution according to experience*

The knowledge aspect of the farmer's

Distributing farmers according to training courses and transferring agricultural expertise: From the histogram (see Table 1 and Figure 2), we noticed that 66.70% of farmers did not exceed secondary school, while 33.3% did. Ninety percent of farmers learned agriculture from their parents or other farmers, and a small group trained in agricultural institutes, which reflects a lack of awareness of modern agricultural techniques and their application in the field. We also notice that most farmers own agricultural land, whether privately owned or inherited, and there is a small group that rents real estate, not exceeding 5%. Thus, agricultural expertise is inherited and passed on from one generation to the next. But because there aren't enough resources, it's only used to provide for the family.

Distribution of farmers according to the exchange of knowledge and resources between farmers

The experience gained by farmers in the date sector of the Beni Abbas oasis has contributed to the progress of agricultural operations (Chehat and Benziouche, 2018). This is because more than 97% of farmers have a spirit of cooperation (see Table 2 and Figure 3), or what is known as "Twiza," especially during the harvest season, as they use simple agricultural tools such as an axe to turn the soil or create a ditch for irrigation, as well as a sickle to harvest the crop. This represents only 2% of the exchange because most farmers own these tools, which are considered traditional. As for large-scale agricultural operations in other products, such as grains, which require plowing vast areas, most farmers rent equipment, and they are a small group.

Table 2: *Distribution of farmers according to the exchange of knowledge and resources.*

Cooperation between farmers		Sharing knowledge		Exchange of resources and equipment	
Yes	Non	Frequently	System	Frequently	System
99%	1%	3%	97%	2%	98%

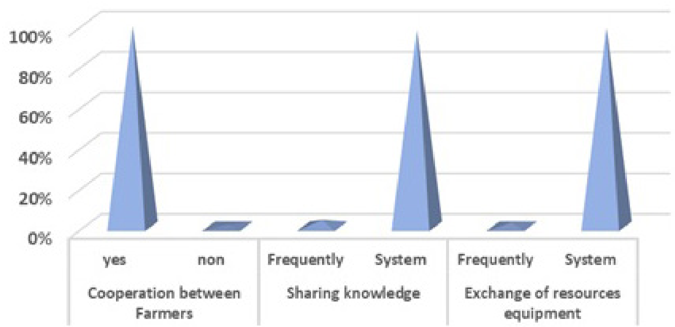

Figure 3: *Distribution of farmers according to the exchange of cooperation, knowledge, and resources equipment.*

The agricultural operations aspect

In the Figure 4 and Table 3, we note that 96.7% of farmers practice traditional crop rotations. Some farmers begin the agricultural season with vegetables, followed by fodder, and then allow the soil to rest. Another group of farmers used two cycles, beginning with fodder and then vegetables. Some fodder plays a crucial role in replenishing the soil and supplying it with certain minerals. 83.3% achieve coverage and quality production using traditional crop rotation methods. Despite the low use of mineral fertilizers, which are very effective in producing good and abundant crops, 93% of farmers use fertilizers. Fertilizing the soil is performed traditionally, or with what is called organic fertilizer from animal remains with a diluted concentration, noting that the best fertilizer is sheep remains.

Table 3: *Methods of treating agricultural land.*

Terraces (%)		Mulching (%)		Crop rotation (%)		Use of fertilizer (%)		Use of pesticides (%)	
No	Yes	Yes	No	Yes	No	Yes	No	Yes	No
3.30	96.70	83.30	16.70	96.70	3.30	93	7	99	1

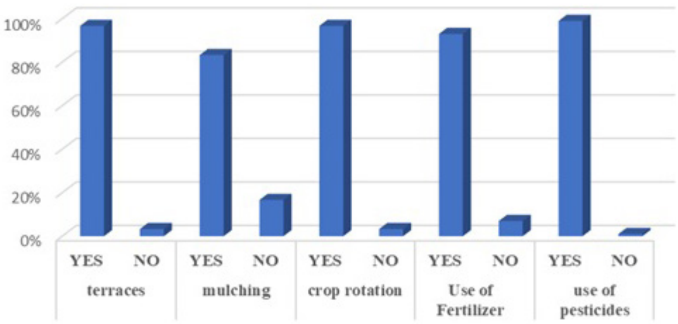

Figure 4: *Methods of treating agricultural land.*

Agriculture in Beni Abbes suffers from seasonal diseases that greatly affect the destruction of crops and the spread of root-cutting insects, as well as the abundance of eggs (Bayoud disease; the pathogen responsible for the disease is *Fusarium oxysporum* f.sp. albedinis) which infects palm trees and affects their yields (Ie, 2017; Mohamed, 2020; Zouari and Abdelhedi, 2020). Therefore, most farmers, 99%, use pesticides and medicines to treat plant diseases under the supervision of the Agricultural Directorate and Plant Protection.

Threats to agriculture and initiatives to maintain biodiversity and water resources

The most important problems and hazards facing the Beni Abbas Oasis: Through a field visit and reviewing the farmers' answers, we note that 90% of farmers believe that climate change (see Table 4 and Figure 5), particularly rising temperatures, leads to soil dryness, which significantly affects water scarcity. 75% of farmers also believe that sand encroachment significantly contributes to the reduction of agricultural areas and increased desertification in the region. We also noted that 68% believe that there is a shortage of well water in some fields due to over-exploitation and continued over-exploitation results in a reduction in agricultural activity during the winter and spring seasons only. Farmers suffer from plant diseases. The lack of advanced agricultural equipment and failure to use mineral fertilizers also contributed to low production yields. This explains why 80% of farmers responses indicated this.

Lack of agricultural guidance, training, and supervision makes farmers reluctant to engage in extensive fruit tree cultivation (Benziouche *et al*., 2015). The shortage of a qualified and young workforce has led some farmers to neglect the requirements of palm cultivation (Bessaad *et al*., 2025). Some farmers have neglected to apply biological and chemical disease control methods. The limited budg*et al*located to agricultural activities has led to a focus solely on self-sufficiency (Giller *et al*., 2021).

Development measures for agricultural activity in Béni Abbes Oasis

The authorities have taken multiple measures to promote agro-development in the Béni Abbes oasis. These would involve the implementation of modern and efficient irrigation regimes and water-efficient agronomic practices, the introduction of young people into modern farming, and the strengthening of extension services. Attention is also being directed at bolstering biodiversity and agriculture with help from nature through protected areas and awareness, recommendations for forage crop management,

Table 4: *The main challenges and threats facing the oasis.*

Climate change		Desertification		Water overexploitation		Advanced agricultural stubbornness		The failure to use mineral fertilizers		The lack of agri-guidance		The lack of budget for agricultural activity	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
90%	10%	75%	25%	68%	32%	80%	20%	80%	20%	70%	30%	90%	10%

mixed crops, natural methods of plant disease control, and the recommended use of mineral fertilizers and experimentation with cold methods. In addition, subsidies can be raised for specific animal products and agricultural zones developed to facilitate the settling of farmers and create a more competitive and sustainable agricultural sector in the territory.

Statistical analysis of agricultural indicator interdependencies

To look at the connections between the important agricultural factors found in the surveys, Multiple Correspondence Analysis (MCA) was used first to understand how the collected categorical data was organized (Table 5).

Table 5: *The indices employed in the MCA analysis.*

The indices	Terms	Meaning
I_1=Education Level: EL	EL 1	illiteracy
	EL 2	Primary school
	EL 3	High School
	EL 4	University
I_2= farming experience: E	E1	1-5
	E2	6-10
	E3	11-20
	E4	More than 21
I_3 = Agricultural training: AT	AT 1	Yes
	AT 2	No
I_4 = Use Agricultural fertilizers	AF1	chemical fertilizers
	AF2	organic fertilizers
	AF3	No fertilizers
I_5 =Exchange of resources: ER	ER 1	Frequently
	ER 2	System
	ER 3	Other
I_6 =Exchange of knowledge: Ek	EK 1	Frequently
	EK 2	System
	EK 3	Cooperation between farmers
I_7= use agricultural pesticides: AP	AP1	Used
	AP2	No used
I_8= climate change: CCH	CCH1	Influencing agriculture
	CCH2	Not affecting
	CCH3	Other
I_9= desertification: D	D1	Sand creep
	D2	Not affecting
	D3	Nothing
I_{10}= water over-exploitation: WE	WE1	Influencing agriculture
	WE2	Not affecting
	WE3	No overuse

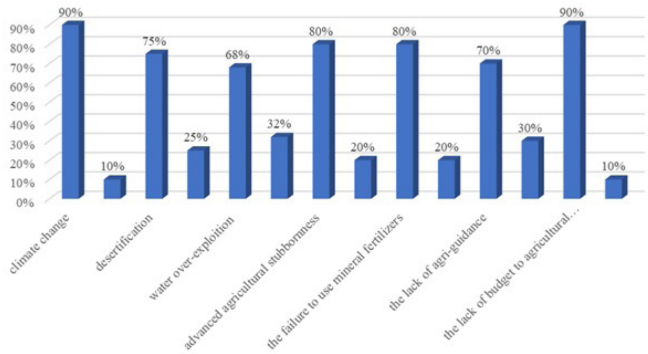

Figure 5: *The main challenges and threats facing the Oasis.*

Models were created to portray the qualitative relationships and patterns of the identified specific sets of indicators. They are offered as relational descriptions rather than predictive mathematical formulas, intended to visually and conceptually encapsulate the dominant dynamics observed in the field.

The results of the indices employed in the MCA analysis

The combination of Education Level, Farming Experience, and Agricultural Training results in Agricultural Knowledge.

The mathematical model that links the education level of farmers and farming experience and agricultural training:

$$\forall f(\mathrm{EL}) = \{\mathrm{EL1}, \mathrm{EL2}, \mathrm{EL3}, \mathrm{EL4}\}, \forall \varphi(E) = \{E1, E2, E3, E4\},, \forall \omega(AT) = \{AT1, AT2\} \Rightarrow$$
$$\begin{cases} \omega(AT) \propto \varphi(E); AT2 \propto \varphi(E) = \{E2, E3, E4\}, AT1 \propto E1 \ (1) \\ \omega(AT) \propto f(\mathrm{EL});\ \omega(AT) = \frac{1}{3} f(\mathrm{EL}) \ (2) \end{cases}$$

The combination of agricultural fertilizers and use of Agricultural pesticides results in agricultural operations.

The mathematical model that links the use of agricultural fertilizers and agricultural pesticides:

$$\forall \delta(\mathrm{AF}) = \{\mathrm{AF1}, \mathrm{AF2}, \mathrm{AF3}\}, \forall \mathrm{X}(AP) = \{AP1, AP2\} \Rightarrow \begin{cases} AF1 \propto AP1 \ (3) \\ AF2 \propto AP2 \ (4) \\ for\ AF3 \Rightarrow AP = x \ (5) \end{cases}$$

The combination of exchange of resources and Exchange of knowledge results in cooperation.

The mathematical model that links the exchange of resources and exchange of knowledge:

$$\forall\vartheta(\mathrm{ER})=\{\mathrm{ER1},\mathrm{ER2},\mathrm{ER3}\},\forall\gamma(EK)=\{EK1,EK2,EK3\}\Rightarrow\begin{cases}\mathrm{ER1}\propto EK1 & (6)\\ \mathrm{ER2}\propto EK2 & (7)\\ for\ EK3\Rightarrow ER=z & (8)\end{cases}$$

The combination of climate change, desertification and water over-exploitation results in Agricultural threats.

The mathematical model that links climate change and desertification and water over-exploitation:

$$\forall\Phi(\mathrm{CCH})=\{\mathrm{CCH1},\mathrm{CCH2},\mathrm{CCH3}\},\forall\Upsilon(D)=\{D1,D2,D3\},,\forall\Omega(WE)=\{WE1,WE2,WE3\}\Rightarrow$$
$$\Rightarrow\begin{cases}\mathrm{CCH1}\propto D1\propto WE1 & (9)\\ \mathrm{CCH2}\propto D2\propto WE2 & (10)\\ D3\propto WE3 & (11)\end{cases}$$

Table 6: *Statistics of agricultural variable functions.*

Agricultural variables functions	f(EL)	φ (E)	ω (AT)	δ (AF)	Φ (CCH)
Skewness	285	-1.441	2.809	3.660	-2.809

The skewness scale (Table 6) quantifies the asymmetry of the distribution of each agricultural variable function.

A positive skewness value (skewness > 0) indicated a right-skewed distribution. In this case, the bulk of the data values are concentrated on the left side (lower values), with a longer tail extending toward the right (higher values). For example: *(f(EL),ω(AT),δ(AF)* are functions of agricultural variables that have skewness>0) exhibit positive skewness, suggesting that for these aspects, lower values are more common, with fewer instances of exceptionally high values.

A negative skewness value (skewness < 0) indicated a left-skewed distribution. Here, the bulk of the data values are concentrated on the right side (higher values), with a longer tail extending towards the left (lower values). For example: *(φ(E),Φ(CCH)* are functions of agricultural variables that have skewness<0) exhibit negative skewness, implying that for these aspects, higher values are more prevalent, with fewer instances of exceptionally low values.

A skewness value close to zero suggests a relatively symmetrical distribution of the variable's values.

Conclusion

Agriculture in the Béni Abbes region has a difficult history, and the examination of practices and constraints in the region demonstrates the extent to which humans have adapted and creatively adapted to the trials of the Algerian Sahara. The findings suggest remarkable flexibility in local farming practices, which are characterized by the development and operation of sophisticated farming systems that balance ecological integrity with financial gain. Although farmers are challenged by compounding problems such as climate change, water stress, and lack of access to modern agricultural technologies, they have a high degree of cooperation and continue to follow their ancestral agricultural techniques. The introduction of animals into crop farming systems and the use of traditional agro-rotation practices illustrate the adaptive potential and resourcefulness of farmers. The dependency on old methods and the limited use of new types of fertilizers show that education and training need to be improved. To promote sustainable development of agriculture, authorities must take appropriate steps, including advanced irrigation systems, popularizing conservation of water measures, and promoting training programs for agriculture. Motivating the youth to adopt modern agricultural practices will also be essential to guarantee the future sustainability of agriculture in Béni Abbes.

Results of a study for the region Béni Abbess, the valuation of traditional knowledge, and the needs for technology and education support are pertinent for development officials and agricultural planners in other semi-arid areas such as Pakistan, where desertification, sustainable water resources management, and smallholder farmer empowerment are critical. The statistical framework employed in the modeling of agriculture in this work can also be used for studying analogous oases or arid farming systems in other locations. In short, the hybrid of the old and the new ways can revolutionize the agriculture of the area of Béni Abbes. The current challenges can be tackled with potential factors that could make farming practices more sustainable for a thriving agriculture sector, which would not only provide income for farmers but also conserve the diversity of plants and animals exclusive to this region.

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Novelty Statement

This research is novel in applying statistical modeling (MCA and Mathematical modeling) to socio-agricultural dynamics in oasis.it uniquely integrates traditional knowledge with modern challenges, offering transferable insights for sustainable agriculture in arid regions.

Author's Contribution

Warda Djoudi: Conceptualization, methodology design, formal analysis and manuscript writing.
Okkacha Youb: Supervision, data collection, validation, guidance and editing of the manuscript.

Generative AI and AI-assisted technology statement
Generative Ai was only used to assist in improving the English language and clarity of expression. All data collection, Statistical analyses, and interpretation of results were performed solely by the authors.

Conflict of interest
The authors have declared no conflict of interest.

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