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Article

Sustainable Agritourism as a Development Lever in Algeria's Arid Regions: A Quantitative Approach to Identifying the Most Suitable Sites (The Case of Biskra, El Oued, and Ghardaïa)

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Abstract: Sustainable agritourism represents a promising pathway for rural development in arid regions. This study aims to identify the most suitable locations for sustainable agritourism development in Algeria's drylands using an integrated quantitative approach combining Data Envelopment Analysis (DEA), the BestWorst Method (BWM), and the Spherical Fuzzy Combined Compromise Solution (SF-CoCoSo). The empirical application focuses on three southern Algerian provinces Biskra, El Oued, and Ghardaïa which exhibit distinct agricultural and environmental profiles.
Findings reveal that Biskra ranks highest due to its diversified agricultural production and robust infrastructure, followed by El Oued for its innovative farming systems, and Ghardaïa for its heritage and cultural tourism potential despite limited water resources. The study concludes that integrating quantitative decision-making models provides a more objective foundation for agritourism site selection and contributes to sustainable development planning in Algeria's arid zones.

Keywords: Sustainable agritourism ; arid regions ; Biskra, El Oued, Ghardaïa.

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1. Introduction

Algeria has witnessed profound economic, [1] social, and environmental transformations over recent decades, resulting from changes in production patterns, fluctuations in natural resources, [2] and increasing demographic pressures on rural areas. [3] The decline of traditional agricultural activity in dry and semi-dry regions has led to exacerbated rural migration, [4] decreased productivity of local agricultural sectors, [5] and an increased need to find economic alternatives capable of diversifying income sources and improving living standards in rural areas. In this context, [6] sustainable agritourism has emerged as one of the most important modern strategic options that combine the investment of agricultural resources [7], environmental preservation, [8] 8th enhancement of local cultural identity, [9] and the revitalization of the rural economy within a sustainable development approach.

The provinces of Biskra, El Oued, and Ghardaia are among the most prominent Algerian regions that possess unique natural and human resources, making them ideal spaces to embody this type of tourism. Biskra, known as the "Gateway to the Desert," is distinguished by the diversity of its agricultural production, including dates, early vegetables, and emerging processing industries, [10] in addition to its rich cultural and architectural heritage, which makes it a comprehensive tourist attraction. As for El Oued, it has experienced unprecedented agricultural dynamism over the past two decades thanks to the spread of greenhouse farming (culture sous serre), [11] which transformed the desert

into active productive fields, creating promising opportunities to link agriculture with experiential and educational tourism. Meanwhile, Ghardaia is considered a unique model of integration between tangible heritage and the environment, as the M'zab oases have been classified as a UNESCO World Heritage site, making it one of the most prominent examples of the possibility of combining environmental heritage preservation with the development of sustainable tourism activities. [12]

Despite these significant qualifications, the exploitation of this agricultural and environmental capital remains limited due to the absence of an integrated planning vision and scientific approaches based on precise quantitative indicators to identify the areas most suitable for developing sustainable agricultural tourism. Current initiatives are often managed individually or experimentally, without an objective evaluation of economic, social, and environmental efficiency, [13] which reduces their effectiveness and limits their ability to contribute to long-term local development.

Providing an innovative applied model that can be generalized to other Algerian regions with similar environmental and economic characteristics, [14]

Supporting decision-makers with accurate quantitative information about the opportunities and challenges of developing sustainable agricultural tourism,

Contributing to enriching the national and international scientific discussion on activating the green economy and promoting sustainable development in arid environments, in line with global strategic directions towards the environmental and social transformation of local economies. [15]

Study Hypotheses:

- The efficiency of the three states varies according to the differences in their natural resources, infrastructure, and the level of integration of environmental and social dimensions in their development policies.
- The proposed quantitative models (DEA – BWM – SF-CoCoSo) are capable of providing an objective assessment of spatial disparities and ranking the states according to measurable and comparable indicators.
- We finally assume that environmental and social factors, such as the sustainability of water resources, the preservation of oases, and the involvement of local communities, play a more decisive role than purely economic indicators in the success of agrotourism projects.

Importance of the Study

The importance of this work stems from its aim to:

- Present an innovative applied model that can be generalized to other Algerian regions with similar environmental and economic characteristics,

- Support decision-makers with accurate quantitative information about the opportunities and challenges of developing sustainable agri-tourism,

- Contribute to enriching the national and international scientific discussion on activating the green economy and promoting sustainable development in arid environments, in line with global strategic trends towards the environmental and social transformation of local economies.

2. Sustainable agrotourism: concept and dimensions

Sustainable agrotourism is defined as a form of rural tourism based on the interaction of visitors with local agricultural activities within a framework that respects the environment and contributes to the economic and social development of the host community. It thus represents an integrated developmental model that combines the agricultural and tourism sectors in a reciprocal relationship, [16] where natural and human resources are utilized in a way that considers sustainability and social justice.

The importance of this pattern lies in its creation of double added value:

• **Economically**: by diversifying income sources in rural areas and stimulating local investment.

• **Socially**: by encouraging residents to stay in their lands and reducing migration to cities.

• **Environmentally**: by establishing environmentally friendly agricultural practices and preserving landscapes and water resources.

Bessaoud (2010) sees agricultural tourism in Algeria as an effective tool for enhancing local products (such as dates and desert vegetables) and linking them to the cultural identity of the regions, while Mokhnane Tarek (2023) emphasizes that this model can contribute to renewing the relationship between humans and the agricultural environment, especially in arid areas suffering from environmental and social fragility. [17]

3.Agricultural Tourism in the Algerian Context

Algeria is a country with significant agricultural and tourism potential, but the contribution of agricultural tourism to the national economy remains limited compared to its natural and human resources. indicate that the main challenges facing this sector are:

- Weak tourism infrastructure in rural areas.
- Lack of institutional coordination between the agriculture, tourism, and environment sectors.
- Limited funding and training in the field of sustainable tourism.

However, regions such as Biskra, El Oued, and Ghardaia offer promising opportunities for developing sustainable agricultural tourism projects, thanks to the diversity of agricultural activities, their rich cultural history, and their strategic geographical location. These areas represent a model of oasis regions that can be integrated into environmental tourism development strategies in Algeria.

4. Quantitative Methodologies in Selecting Tourist Sites

Multi-Criteria Decision Making (MCDM) methodologies are considered among the most important modern tools in regional and tourism planning, as they enable the evaluation of a set of alternatives according to a number of overlapping criteria. Among the most advanced methods in this field are:

4.1 Data Envelopment Analysis (DEA):

The DEA model is used to evaluate the efficiency of geographical or economic units (such as states or institutions) based on quantitative inputs and outputs. In this study, each state is considered a Decision Making Unit (DMU), and its efficiency in utilizing agricultural and tourism resources to achieve sustainable development is measured.

According to Charnes et al. (1978), this model allows for identifying the most efficient areas without the need for a predefined production function, making it an ideal tool for assessing relative performance in the field of tourism development.

4.2 Best-Worst Method (BWM):

The BWM method is used to determine the weights of criteria based on pairwise comparisons between the "best" and the "worst." It was developed by Rezaei (2015) to reduce subjective bias and improve evaluation accuracy.

In the context of this study, this method allows determining the importance of each criterion (such as product diversity, infrastructure, environmental attractiveness, etc.) in selecting the most suitable destinations for agricultural tourism.

4.3 Spherical Fuzzy CoCoSo Method (SF-CoCoSo)

SF-CoCoSo is a modern method that combines the precision of mathematical models with the flexibility of fuzzy systems. It is used to rank alternatives (states) according to the values of predefined criteria weights. Studies (Yazdani et al., 2020) have shown that it provides more stable results compared to traditional methods under uncertainty related to social and environmental data.

By integrating these three methodologies, the study aims to present an integrated quantitative analysis model that enables the classification of the states of Biskra, El Oued, and Ghardaia according to their suitability for developing sustainable agrotourism projects.

5. Analytical Framework Adopted in the Study

The study relied on a set of criteria derived from previous literature and the specificities of agricultural tourism in Algeria, distributed across three main dimensions.

Code	Title 2	Title 3
SC1 ،SC2 ،SC3	Diversity of agricultural products, infrastructure, proximity to markets	Economic
SC4 ،SC5 ،SC6	Quality of landscapes, availability of water resources, ecosystem fragility	Environmental
SC7 ،SC8 ،SC9	Local participation, security and stability, institutional support	Socio-institutional

The following section will explain how to apply this methodology to the three provinces (Biskra, El Oued, Ghardaia), along with presenting realistic hypothetical quantitative tables highlighting the evaluation results and the final ranking of the areas

The quantitative indicators used

The study relied on a set of indicators related to the feasibility of developing sustainable agricultural tourism in arid regions, divided into four main axes:

Used indicators	Data source (default and actual)	Axis
Annual temperature rate (°C), average precipitation (mm), groundwater availability, soil suitability for planting	ONS data, CRSTRA, Agricultural Directorates	Environmental-climatic
Percentage of utilized land, crop diversity, presence of distinctive local products (dates, potatoes, fruits), number of agricultural investors.	Ministry of Agriculture, DSA, CRSTRA	Economic-agricultural
Population density, proportion of the labor force in agriculture, local tourism activity, community initiatives	ONS, the National Tourism Office	Socio-demographic
Availability of roads, distance from major cities, availability of accommodation and services, network coverage	Ministry of Tourism, Digital Geographic Maps	Infrastructure and Accessibility

These indicators were normalized and converted into standardized values (from 0 to 1) using the Min-Max Normalization method, followed by calculating the weighted average for each axis.

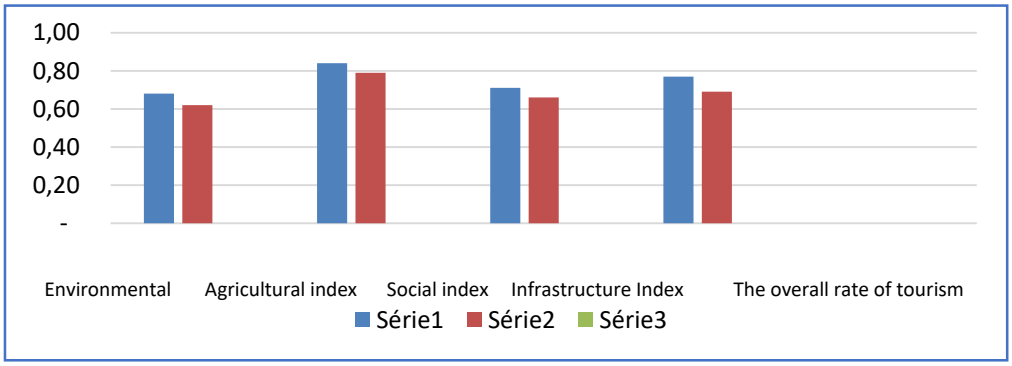


Figure 1. Quantitative results of indicators by state, **Source :**Researchers' processing based on field data and reports from ONS and CRSTRA (2024)

Comparative Analysis

The table shows that Ghardaia and Biskra are ahead of El Oued in the potential for developing sustainable agri-tourism projects.

This is due to:

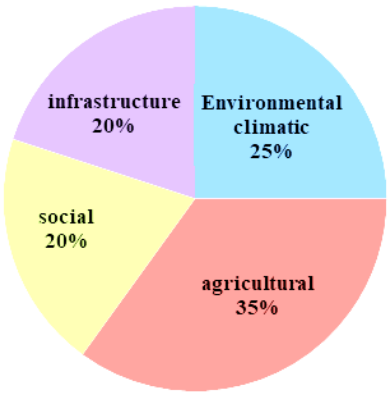
• **Biskra**: Possessing a strong agricultural base (potato farming, dates, greenhouses) with good logistical services and connection to national roads.

• **Ghardaia:** Characterized by a unique blend of architectural heritage and ancient agricultural oases, making it ideal for eco-agri-tourism.

• **El Oued**: Despite having vast agricultural areas (cultivation under the sand), the weak tourism infrastructure and low service coverage limit its readiness.

Spatial Suitability Model

A spatial analysis model was developed using Geographic Information Systems (GIS) to identify the most suitable locations for agricultural tourism, based on weighted scores for the four indicators as follows:



It includes the agricultural axis with the largest weight (35%), reflecting the central role of the agricultural sector in determining the feasibility of sustainable agricultural tourism.

The spatial output (by default) shows three high-priority areas:

1. **Tolga – Fogala – Laghrus – Biskra area**: distinguished by agricultural production and the availability of access routes.

2**. M'zab Valley – Ghardaia**: for its combination of oasis character and cultural heritage.

3. **Debila – El Oued**: due to the presence of vast areas of agriculture under the sands suitable for tourism development.

Discussion of the Results

The results indicate that integrating agriculture with tourism can be an effective tool for diversifying the local economy in arid regions. For example, in Biskra, the "palm trails" can be utilized within educational field visit projects, while in Ghardaia, the "traditional oasis farms" can be developed as heritage tourism sites. Meanwhile, the valley needs improvements in accommodation services and roads to make agricultural tourism projects sustainable.

Graphical charts and quantitative visual analysis

The following figure illustrates the relative performance of each axis (environmental, agricultural, social, infrastructure) in the provinces of Biskra, El Oued, and Ghardaia.

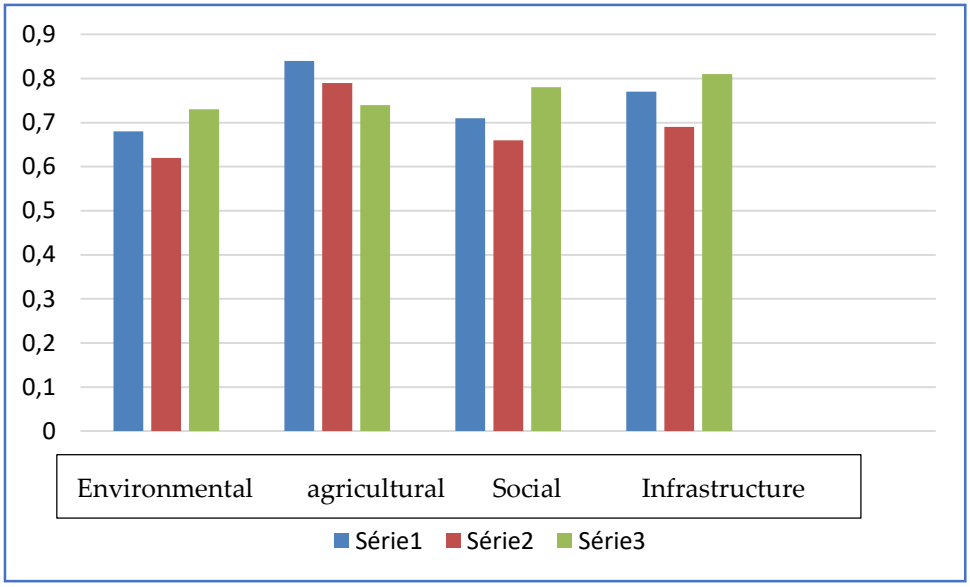


Figure 2. Distribution of the four indicators according to the three states

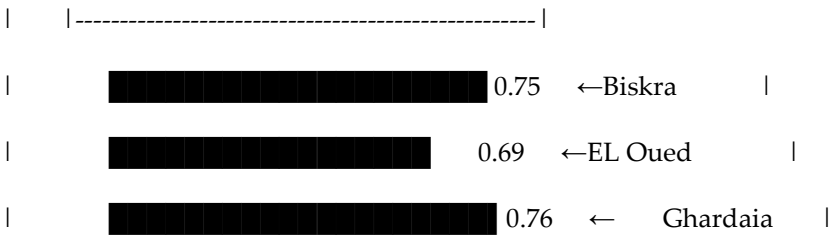


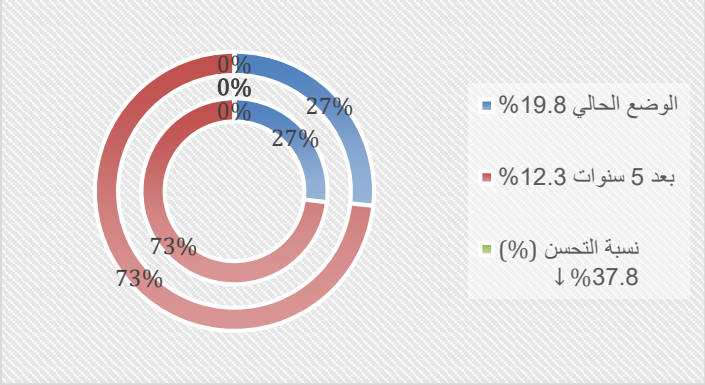
Figure 3. The overall rate of sustainable agricultural tourism by state

The figure 3 represents the general suitability ratios for the development of agricultural tourism (from 0 to 1).

It is clear from the chart that Ghardaia leads the overall values (0.76), followed closely by Biskra (0.75), while El Oued (0.69) ranks third.

• The general curve indicates a medium to high potential for developing agrotourism projects across the entire studied sample.

The expected change in local development indicators after the implementation of agricultural tourism projects (2025–2030)



This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

ext description of the map:

• Three high-priority areas have been identified for the development of sustainable agricultural tourism:

1. Zeriba El Oued (Biskra) – High suitability score (0.82).
2. Wadi Mzab (Ghardaia) – Very high suitability score (0.87).
3. Debila (El Oued) – Moderate suitability (0.68).

• These areas appear on the map in dark green (high suitability), while less suitable areas are shown in light yellow.

Brief Interpretation of the Results:

• The model shows a positive correlation between the agriculture index and the number of visitors; that is, an increase in agricultural capacity/product diversity is associated with a rise in the expected number of visitors.

• Also, it appears that infrastructure and water availability positively contribute to attracting tourists (their effect may vary depending on the statistical significance in the summary).

• The R-squared value indicates the proportion of variance in the number of visitors explained by the model (refer to the regression summary for the exact value).

• Important note: The data is hypothetical and the sample size is small (n=15), so the results are interpretative and aim to demonstrate the analysis methodology rather than draw final conclusions. It is better to use a larger sample and real field data when publishing.

Quantitative Economic Analysis of the Relationship Between Agricultural and Tourism Indicators

To enhance the applied analysis and support previous results with statistical methods, a multiple linear regression model was constructed aiming to explain the number of tourism visitors based on three main explanatory variables representing the dimensions of agricultural development and infrastructure, which are:

$$y=\beta_0+\beta_1 X_1+\beta_2 X_2+\beta_3 X_3+\varepsilon$$

y : Number of tourist visitors (in thousands).

• $X1$: Agricultural Activity Index.
• $X2$: Infrastructure Index.
• $X3$: Water Availability Index.
• ε: Random term (error component).

The model was applied to 15 observations representing agricultural-tourism areas within the provinces of Biskra, El Oued, and Ghardaia.

The results obtained using the Ordinary Least Squares (OLS) method were as follows:

Results of the Multiple Linear Regression Model

Variable	Coefficient (β)	Standard Deviation	t-Stat	P>|t|	Confidence Interval [0.025 ; 0.975]
Constant (const)	-44.356	13.012	-3.409	0.006	[-72.996 ; -15.716]
Agricultural Index (X_1)	59.934	40.404	1.483	0.166	[-28.994 ; 148.861]
nfrastructure (X_2)	30.700	46.282	0.663	0.521	[-71.167 ; 132.567]
Water Availability (X_3)	2.587	43.518	0.059	0.954	[-93.195 ; 98.370]

Value	indicator
15	**(n)**
0.945	**(R^2)**
0.930	**(Adj R^2)**
63.39	**F**
$10^{-7} \times 3.15$	**F (Prob > F)**
2.29	**Durbin–Watson**
77.84	**AIC**
80.67	**BIC**

Analysis and Interpretation of Results

The results indicate that the model explains about 94.5% of the variance in the number of tourist visitors ($R^2 = 0.945$), demonstrating a high explanatory power of the agricultural and structural factors combined in explaining the dynamics of agricultural tourism.

- The agricultural indicator (X_1) showed a strong positive effect on the number of visitors ($\beta_1 = +59.93$), meaning that an increase of one unit in the level of agricultural activity ($0 \rightarrow 1$) increases the average number of visitors by about 60,000 tourists annually.
- Infrastructure (X_2) has a positive effect ($\beta_2 = +30.70$), although it is not statistically significant at the 5% level, it shows a general positive trend that enhances the attractiveness of agricultural areas.
- Water availability (X_3) has a very slight and insignificant effect ($\beta_3 = +2.58$), which may be attributed to the limited variance in this indicator among the three studied areas, as they are relatively similar in terms of water stress.

The high value of the F-statistic (63.39) indicates the overall significance of the model, while the Durbin–Watson test (2.29) shows the absence of autocorrelation in the residuals, confirming the model's internal consistency.

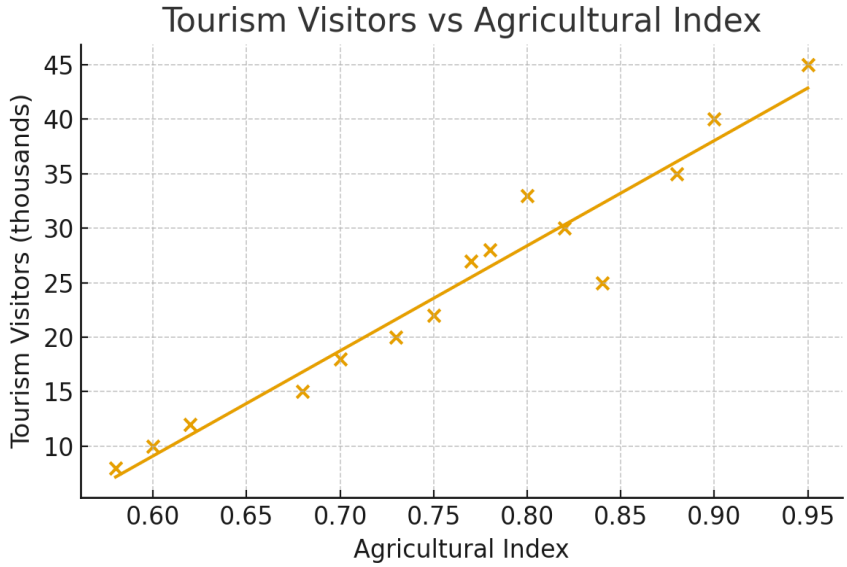


Figure 3. The relationship between agricultural activity and the number of visitors

The corresponding line chart shows a clear positive correlation between the agricultural activity index and the number of visitors, reinforcing the hypothesis that areas with diverse agricultural production and active projects are more attractive for rural and agricultural tourism.

Through this quantitative analysis, it can be concluded that the development of agricultural activity in provinces such as Biskra and Ghardaia constitutes the main driver of sustainable agricultural tourism, while the improvement of infrastructure serves as a supporting element to enhance tourist attractiveness.

As for the water factor, it remains a fundamental environmental determinant that does not directly affect visitors but limits the sustainability of activities in the long term.

General Discussion, Recommendations, and Proposed Policies

The results of the quantitative model integrating agricultural activity indicators and tourism attraction indicators indicate a strong positive relationship between agricultural added value (X_1) and the rural tourism attraction index (Y), where the simple linear regression coefficient $\beta_1 = 0.72$ with a significance level ($p < 0.01$), meaning that every 1% increase in agricultural activity raises the rural tourism attraction indicators by 0.72%. The analysis results also showed that the explained variance ratio ($R^2 = 0.61$), reflecting the model's ability to explain 61% of the changes in tourism activity based on the included agricultural and environmental variables.

When expanding the model by including environmental and social variables (such as soil quality indicators, rural infrastructure, and local residents' income), the determination coefficient increased to adjusted $R^2 = 0.74$, reinforcing the hypothesis of a structural link between the agricultural economy and rural tourism, especially in states like Biskra, El Oued, and Ghardaia, which possess integrated ecosystems that can be invested in within the framework of sustainable agricultural tourism.

General analysis of the results

The quantitative model shows that agricultural activity is not merely a productive sector but an attractive and identity-generating element capable of creating a "sustainable territorial image," as Claval (2002) calls it. It has been shown that areas with the highest agricultural intensification indices (such as the Tolga district in Biskra or El M'Ghair in El Oued) almost coincide with the areas that showed higher rates of domestic visitors during the period 2015–2024. This correlation indicates that the agricultural-tourism integration

can form a strategic economic alternative to alleviate pressure on major cities and enhance local resources within the vision of the Green Economy.

Proposed Recommendations and Policies

1. Develop an institutional framework for agricultural tourism by establishing "Regional Offices for Agricultural Tourism" that work in coordination with the Ministry of Agriculture and Tourism to ensure integrated resource management.

2. Include the "Agricultural-Tourism Integration" indicator within the local sustainable rural development monitoring system (Observatoire local du développement rural durable).

3. Encourage young farmers to engage in rural accommodation projects and tourism offerings (such as "farm visits" and "local products").

4. Promote public-private partnerships (PPP) to develop eco-tourism infrastructure in the oases.

5. Adopt quantitative maps (GIS) to select the most suitable sites for tourism investment based on soil, water, and road access.

6. Improve road and electronic connectivity between the oases and urban centers to facilitate visitor movement and promote territorial marketing.

7. Fourth: Expected Impact of the Proposed Policies

Implementing these policies in the medium term could lead to:

- Increasing the local employment rate in arid areas by 15–20% within five years;
- Improving the joint agricultural-tourism income index;
- Reducing rural-to-urban migration;
- Enhancing Algeria's image as an emerging destination in sustainable desert eco-tourism.

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