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Socio-Economic Approach to Agroforestry Practices and Agricultural Development of the Senalba Chergui Forest in Algeria

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ABSTRACT
Agroforestry's multifunctionality should be central to sustainable agriculture policies in the Algerian steppe due to its social acceptability, economic profitability, and environmental friendliness. A socio-economic approach to agroforestry practices in the Senalba Chergui forest (W. Djelfa) has enabled us to establish a typology of the agroforestry systems practiced in agricultural farms. The use of the concept of externalities with the Green Dam and internalities among the sub-systems of locally practiced agroforestry demonstrates significant social efforts to build the acceptability of agroforestry. This is a key factor in ensuring environmentally sustainable agriculture that protects soils, preserves biodiversity, enhances the quality of agricultural products, safeguards human health, and promotes local settlement.
A multivariate statistical analysis (AFC) provided an overview of the constraints, perspectives, and agroforestry strategies of the farmers and their farms. Therefore, considering the multifunctionality of agroforestry systems in agricultural policies necessitates the design of decentralized processes as a "sine qua non" condition for the effectiveness of the agroforestry system in the Green Dam and the Algerian steppe.

Keywords; Agroforestry; multifunctionality; sustainable development; Senalba Chergui forest; Green Dam; Algerian steppe.

Introduction

Agroforestry in the Algerian steppe, whether within, on the peripheries of the Green Dam, or in steppe zones, promotes the development of fruit and forest arboriculture. These systems demonstrate resilience to limiting factors such as aridity and active lime and act as key enablers for sheep farming, a core component of a sustainable agroforestry system. Furthermore, agroforestry serves as an effective tool for combating desertification by reinforcing the Green Dam's impact and alleviating the degradation of natural environments in arid and semi-arid areas. This degradation has significantly intensified in recent decades due to accelerated population growth, socio-economic changes, and the simultaneous transformation of natural resource exploitation systems.

The expansion of rainfed cereal cultivation in steppe zones, increasing livestock numbers, and inappropriate resource management practices have resulted in various degradation processes (Nedjimi, 2012). These include deforestation, overharvesting of vegetation, overgrazing, soil erosion, and a decline in soil fertility (Le Houérou H.N., 2006). Currently, the Algerian steppe supports only 4 million sheep out of the 22 million estimated in the region, highlighting the urgent need to consider agroforestry as a central component of sustainable development in suitable steppe areas.

In the Algerian steppe, human pressure on natural resources has triggered numerous ecological disturbances, threatening entire ecosystems with increasingly severe degradation. Historically, the steppe ecosystem maintained balance through a rigid harmony between humans and their environment, upheld by ancestral practices that ensured the sustainability and regeneration of natural resources. However, in recent decades, this territory—once characterized by nomadism and large-scale transhumance—has undergone profound changes (Nedjimi, 2012). These changes include the introduction of new practices unfamiliar to the traditional lifestyle of steppe populations (Nedjraoui and Bédrani, 2008). The consequences of these transformations are widespread degradation, affecting every level of the steppe territory.

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One of the main objectives of this study is to identify conceptual and practical tools for the sustainable use of biodiversity in the Senalba Chergui area. Improving the living conditions of the local population while conserving the forest resources of the Green Dam requires reducing the pressure from agricultural demands. By developing sustainable agroforestry on arable lands, this approach paradoxically serves as both a conservation tool for the forest and a means to address the immediate needs of local farmers and herders residing near the Senalba Chergui forest.

Our work includes a descriptive socio-economic methodological approach in the bibliographic section, followed by an analytical method that utilizes scientific tools and techniques, including a questionnaire, based on field observations. This is covered in the tools, methods, and data analysis section.

To justify the choice of this study, the theme was defined based on the apparent ease of working on the state forest of the Green Dam, *Senalba Chergui* (Djelfa), given its territorial importance as a semi-arid forest zone. Its ecological value makes it a particularly interesting case study. Viewing agroforestry exploitation in the Senalba forest as a distinct entity allows for its definition and analysis independently of its role in Algeria's agricultural land-use policies. This work assumes a gradual effort to raise awareness of the immediate reality of agroforestry, a relatively new concept in Algeria's bibliography and research.

Materials and Methods

1.Geographical Location of Senalba Chergui

The Senalba Chergui forest is situated in the Ouled Naïl Mountains, approximately 300 kilometers south of Algiers and a few kilometers west of the city of Djelfa (Figure 35). It serves as the eastern extension of the Senalba Gharbi forest. Geographically, it lies between 34°36' and 34°42' North latitude and 3° and 3°12' East longitude. The Senalba Chergui massif forms the main chain of the Ouled Naïl Mountains and is bordered as follows:

- **To the North**: By the Zoubia depression, with altitudes ranging between 960 meters and 1100 meters.
- **To the East**: By National Road No. 1, which connects Algiers to the Saharan cities via Djelfa, with a 10-kilometer segment bordering the forest.
- **To the South**: By Road No. 164, linking Djelfa to Charef, with a 3.5-kilometer section delineating the forest boundary.
- **To the West**: By a wide strip of barren land traversed by the tributaries of Oued Zoubia (BNEF, 1984a).

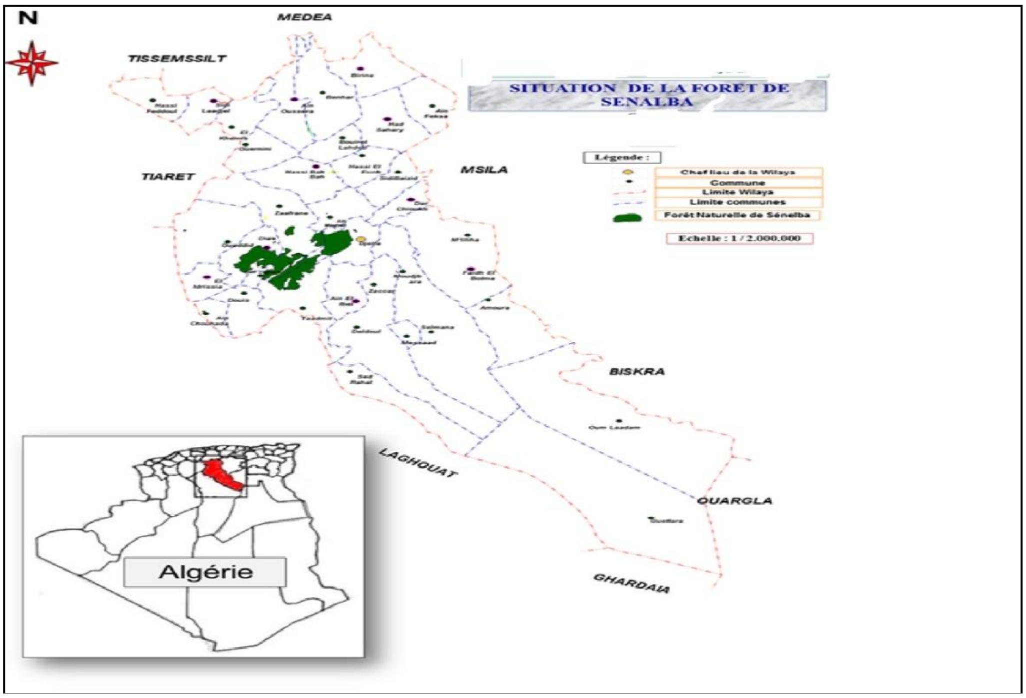

Figure 1. Location Map Relative to Administrative Boundaries

The Senalba forest is a natural forest predominantly composed of Aleppo pine (*Pinus halepensis*).

Figure 2. Senalba Chergui Forest

2. Methodology and Typology of the Agroforestry System in Senalba Chergui

The methodology and typology selected for the agroforestry farms in Senalba Chergui are based on the functional concept of agroforestry operations. These operations are located within the forest and embody the interface between the forest system and the agroforestry system. This is achieved through the integration of forest trees with fruit tree cultivation, combined with existing ovine livestock farming. Agroforestry is defined here as: *"An integrated system for managing rural land resources that intentionally associates trees or shrubs with crops or livestock, creating interactions that generate economic, environmental, and social benefits"* (De Baets et al., 2007).

2.1. Methodology

Our methodology does not follow a classical approach but serves as a preliminary effort to identify issues and propose a specific investigative framework for the agroforestry system of the Senalba forest. It is based on leveraging a range of bibliographic information on the Djelfa region and the Senalba forest (reports, monographs, statistics, and publications) and conducting a zoning analysis of the study area to identify representative study sites.
Subsequently, we conducted surveys at agricultural holdings to analyze the current situation, establish a functional typology, identify major constraints, and provide recommendations.

2.3. Selection of the Region and Survey Sites

Etymologically, the term "region" refers to any division of space, whether large or small. A natural region, theoretically defined by its physical unity, also encompasses human elements that manifest in the landscape, whether agricultural or urban.
For understanding the functioning of agroforestry systems, the regional scale remains the most appropriate territorial entity. At this scale, specific environmental determinants combine with social organization to produce particular production systems.
Each zone must be homogeneous while maintaining agroecological diversity compared to other areas. In this case, the Senalba Chergui forest is a well-defined ecological forestry entity. Our study region is situated within an agroforestry environment that can be assessed at both minimal levels (plot or farm) and larger scales.
Following this, a preliminary questionnaire was developed, and contact was established with technical and administrative support structures to gather information on agroforestry in the Senalba Chergui region.

2.4. Preliminary Survey and Field Investigation

This phase lasted approximately one month, from late January to late February. Its objective was to:
- Gather information on agroforestry and the farmers practicing this system.
- Familiarize ourselves with the preliminary questionnaire, test it, and make necessary corrections.
- Conduct initial field observations.

2.5. Sampling

The sample size for the survey consisted of 40 farms. According to data from the agricultural services department and the forestry directorate of Djelfa, these farms represent:
- 55% of the total identified farms in Senalba Chergui.

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• 100% of farms meeting the criteria of introducing fruit and forest trees into the primary ovine farming activity.
This approach avoided regional stratification despite the organization of farms into six groups and six types.
The selection criteria for farms in each area were:
• Integration of fruit and forest trees with ovine farming.
Accessibility to farms and the cooperation of farmers.

Table 1. The different types of agroforestry systems in Senalba Chergui, including the area of trees, farm size, livestock, and other characteristics.

4o miniType	*Area of Fruit and Forest Trees (ha)*	*Total Area of Farm (ha)*	*Number of Ovine Heads*	*Area of Cereal Cultivation (ha)*	*Area of Forage Crops (ha)*	*Area of Greenhouse Vegetable Cultivation (ha)*	*Educational Level*	*Age of Farmer (years)*
1	2-6	20-25	100-120	< 5	< 1	-	Intermediate/Secondary	20-40
2	6-8	> 100	80-100	10-20	1-2	< 0.16	Primary/Quranic	40-60
3	> 12	20-60	-	> 30	> 16	< 0.16	Primary/Quranic	> 60
4	3-4	3-6	40-50	None	None	0.16-0.32	Intermediate/Secondary	18-40
5	1-2	9-20	80-100	5-10	< 1	-	Intermediate/Secondary	18-40
6	4-8	25-40	100-120	5-10	8-16	-	Primary/Quranic	41-60

2.6. Conducting Field Surveys

The surveys were conducted through direct interviews with farmers on their farms using a structured questionnaire. The goal was to better understand the farm's current situation.
This operation lasted 18 months, from December 2014 to April 2016, and involved 40 farms within Senalba Chergui. Multiple visits were made to each farm to build trust and collect all necessary information, requiring significant travel efforts.

2. 7. Data Processing and Analysis

The collected data were standardized to ensure consistent and rational analysis. Two approaches were employed during this phase :

1. **Analytical Approach**
2. **Statistical Approach** using Simple Correspondence Factor Analysis (SCFA).
3. This table summarizes the different types of agroforestry systems in Senalba Chergui, including the area of trees, farm size, livestock, and other characteristics.

Results and Discussion

3.1. Analytical Approach of the Operator and the Farm

3.1.1. The Operator

3.1.1.1. Age of the Operator

The majority of operators (30 individuals, or 75%) fall within the age range of 18 to 35 years, making this the most active age group. This reflects the high level of interest and support from agricultural programs aimed at developing fruit tree farming and agricultural diversification, as well as sheep farming and forest-related support initiatives. In contrast, 10 operators (25%) are aged between 40 and 60, representing a more experienced group, primarily focused on livestock farming. Data from administrative services indicate that these operators are registered with the Djelfa Chamber of Agriculture, an institution with a unique "consular" status, collaborating with regional agricultural services and overseen by elected representatives. While these operators are affiliated with the Chamber of Agriculture, they do not form a distinct agroforestry association. They hold farmer identification cards and are covered by the National Social Security Fund for self-employed individuals (CASNOS), ensuring their retirement plans. The age indicator highlights that younger operators, who are more open to innovation and new practices, play a significant role in the adoption of agroforestry.

3.1.1.2. Educational Level of the Operator

A large proportion of operators have low educational attainment. About 40% have completed Quranic schooling, while 30% possess primary-level education. The remaining 30% have an intermediate or secondary level of education, enabling them to better understand modern farming techniques and biological cultivation. The smallest group comprises those with university-level education (10%), expected to promote sustainable agroforestry systems. The educational level correlates with the willingness to adopt innovations and contributes to the social acceptability of agroforestry.

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3.1.1.3. Household Size
Household size is generally significant, with 40% of operators having 4 to 8 members and 35% having more than 8. This is influenced by socio-religious factors and a lack of awareness. Younger operators, typically aged 20 to 40, are more likely to have smaller households (1 to 4 members) due to age and education. The structure of household size impacts the social acceptance of agroforestry, underlining the importance of understanding agricultural practices in rural integration and family labor contributions. The farming role reflects established traditions and adapts to contemporary rural dynamics.

3.1.1.4. Place of Residence
A majority (55%) of operators live in agricultural areas, while 45% reside outside these zones due to the remote nature of their farms. Only 35% live on-site, with sufficient financial means to build their homes on the property. The location indicator shows that residence affects territorial organization, mobility, and the integration of agroforestry activities, impacting the agricultural landscape in Senalba Chergui.

3.1.1.5. Origin of the Operator
Around 45% of operators are from the local forest area, living within the surveyed farms. The majority are well-adapted to harsh winter conditions and supported by state subsidies, displaying a strong commitment to farming. Meanwhile, 20% come from other regions, such as Djelfa and Hammam Charef, and belong to local tribes. This origin indicator highlights that agroforestry is widespread among the community, fostering cooperation and shared technical efforts within familial and local networks.

3.1.1.6. Secondary Activities
The majority (87.5%) of operators do not engage in secondary activities, partly due to prior unemployment and a lack of qualifications that limit opportunities in other sectors. The preferred activities are agriculture, livestock, and agroforestry, which provide sufficient income. A minority (7.5%) are involved in commerce, and 2.5% in entrepreneurship, often lacking formal expertise but leveraging financial resources to create integrated operations. A few (2.5%) are salaried employees, and 5% work in construction. This indicator shows that agroforestry operators may participate in diverse activities, either individually or collectively, reflecting the extension of agricultural enterprises and wage employment.

3.1.2.7. Area of Open-Field Vegetable Crops
• **Distribution of Areas**: For 45% of the farms, the area dedicated to open-field vegetable crops ranges from 0.04 to 0.08 hectares. This is followed by 22.5% of farms with areas between 0.08 and 0.16 hectares. For 15% of farms, the area is less than 0.04 hectares, while 12.5% have areas between 0.16 and 0.32 hectares, and 5% of farms have an area ranging from 0.32 to 0.64 hectares.

• **Challenges and Factors**: These crops, despite being marginal in size, include a wide range of species and varieties. The limited area is due to the lack of knowledge among farmers about the various cultivation techniques, water scarcity during the summer months, and the primary focus on sheep farming. This is why open-field vegetable cultivation is typically practiced in the spring and used for supplementary income.

• **Indicator Analysis**: The open-field vegetable crop area reflects a strategy that supports agroforestry efforts aimed at wealth creation. Diversifying plant material helps spread harvest periods. The farmers in Senalba Chergui cultivate varieties best suited for productivity and good storage, with active participation from producers.

3.1.2.8. Area of Greenhouse Vegetable Crops
• **Distribution of Areas**: A significant 60% of farms do not practice greenhouse vegetable farming. Among the remaining farms, 20% have an area between 0.08 and 0.16 hectares, 17.5% have an area between 0.32 and 0.64 hectares, and only 2.5% of farms have areas greater than 0.64 hectares.
• **Potential and Constraints**: Although these areas are small, they represent a significant opportunity for investment. Greenhouse farming, or plasticulture, is relatively new in Senalba Chergui and requires high technical expertise and resources. The limited education levels and financial means of farmers pose significant barriers to the development of this practice.
• **Indicator Analysis**: The area of greenhouse crops shows an openness among agroforestry farmers toward intensive farming as a response to climate challenges, such as frost in the semi-arid steppe climate.

3.1.2.9. Area of Cereal Farming
• **Distribution of Areas**: The majority (87.5%) of farms practice intercalary cereal farming for sheep feed, extending beyond their plots into available land (except forested areas, which are prohibited). For 7.5% of farms, the cereal area is less than 5 hectares, and for 5%, the area ranges from 10 to 20 hectares.
• **Challenges**: The main issue is the high investment required for cereal farming, which most farmers cannot afford.

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• **Indicator Analysis**: The cereal farming area indicates that sustainable management practices in agroforestry can create synergies between cereal cultivation and sheep farming. The waste produced by one component serves as a resource for the other—manure improves crop production, while crop residues provide feed for livestock.

3.1.2.10. Area of Forage Crops

• **Distribution of Areas**: For 35% of farms, no forage crops are cultivated. For 65%, the area dedicated to forage crops is less than 1 hectare. These crops are essential for livestock feed and the local market and are the second most common type of crop after fruit cultivation.
• **Importance**: Forage crops are crucial for sheep farming and some cattle units, highlighting the integration of livestock in the agroforestry system.
• **Indicator Analysis**: The area of forage crops emphasizes the importance of sheep farming in Senalba Chergui's agroforestry system. The integration of forage crops supports the growing demand for livestock products in the region.

3.1.2.11. Livestock Farming

• **Practices and Distribution**: Sheep farming is a primary activity for 100% of farms, with 75% owning between 100-120 sheep, 25% between 50-75 sheep, and all farms also keeping goats. Cattle farming is limited, with 30% of farms having a few head of cattle.
• **Challenges and Management**: Goats can damage fruit and forest trees inside and outside the plots. Effective organization and management of livestock and land are essential, especially in restricted grazing areas like the forested areas of Senalba under the "Green Barrage."
• **Indicator Analysis**: Livestock farming within agroforestry systems requires expertise in animal health and nutrition, which can be learned through experience. The use of sheep manure boosts crop yields, enhances soil health, reduces erosion, and increases productivity. Including animals in agroforestry systems improves sustainability by reducing reliance on external inputs, combating poverty and malnutrition, and supporting environmental sustainability. However, carbon storage can be negatively impacted by methane emissions from livestock.

3.2. Statistical Approach (AFC) of the Farmer and the Operation

This approach identifies groupings of variables and individuals that share similar characteristics, represented in a two-dimensional plane (Plan 1-2). The contribution of each principal axis to the total variation is calculated by summing the individual contributions of each axis. For simplicity, the variables are displayed on a single two-dimensional graph, facilitating a quick and comprehensive view.

Contribution of the Principal Axes

• **Axis 1**: 19.2%
• **Axis 2**: 12.5%
• **Axis 3**: 11.4%
• **Axis 4**: 8%
• **Axis 5**: 7.3%

The total percentage explained by the first two axes (Plan 1-2) is:
• **Plan 1-2**: 19.2% + 12.5% = 31.7%
The percentage explained by the third and fourth axes (Plan 3-4) is:
• **Plan 3-4**: 11.4% + 8% = 19.4%
Only the first two axes are retained since they account for 31.7% of the total information, compared to 19.4% for the next two axes.

Variables Contribution Analysis

• **Axis 1**: The variables that contribute the most to the inertia of this axis include:
  ○ Total area of the operation (STE)
  ○ Integration of sheep farming within the agroforestry system (ELVO)
  ○ Integration of cereal farming within the forest system (SCCI)
  ○ Integration of forage crops within the forest system (SCFI)
• **Axis 2**: The variable contributing most negatively to the inertia of this axis is:
  ○ Artisan activities using wood from forest trees
• **Axis 3**: The variables that contribute most to the inertia of this axis (negatively) are:
  ○ Integration of greenhouse vegetable farming within the agroforestry system (CUMIS)
  ○ Artisan activities integrated within the agroforestry system While the following variables contribute positively to Axis 4:
  ○ Type of planting in the forest system (TPL)
  ○ Spacing between tree rows (ECPA)
• **Axis 5**: The variable contributing positively to this axis is:

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○ Secondary activities of the farmer (ASE)

Individual (Farms) Analysis

An examination of the farms shows that elements related to the farmer's profile contribute positively to all axes (1, 2, 3, 4, and 5). This indicates that agroforestry practices are well-integrated into the farms and have strong social acceptability within the farming community. The data suggest that the adoption of agroforestry practices aligns with the broader agricultural activities of the farms.

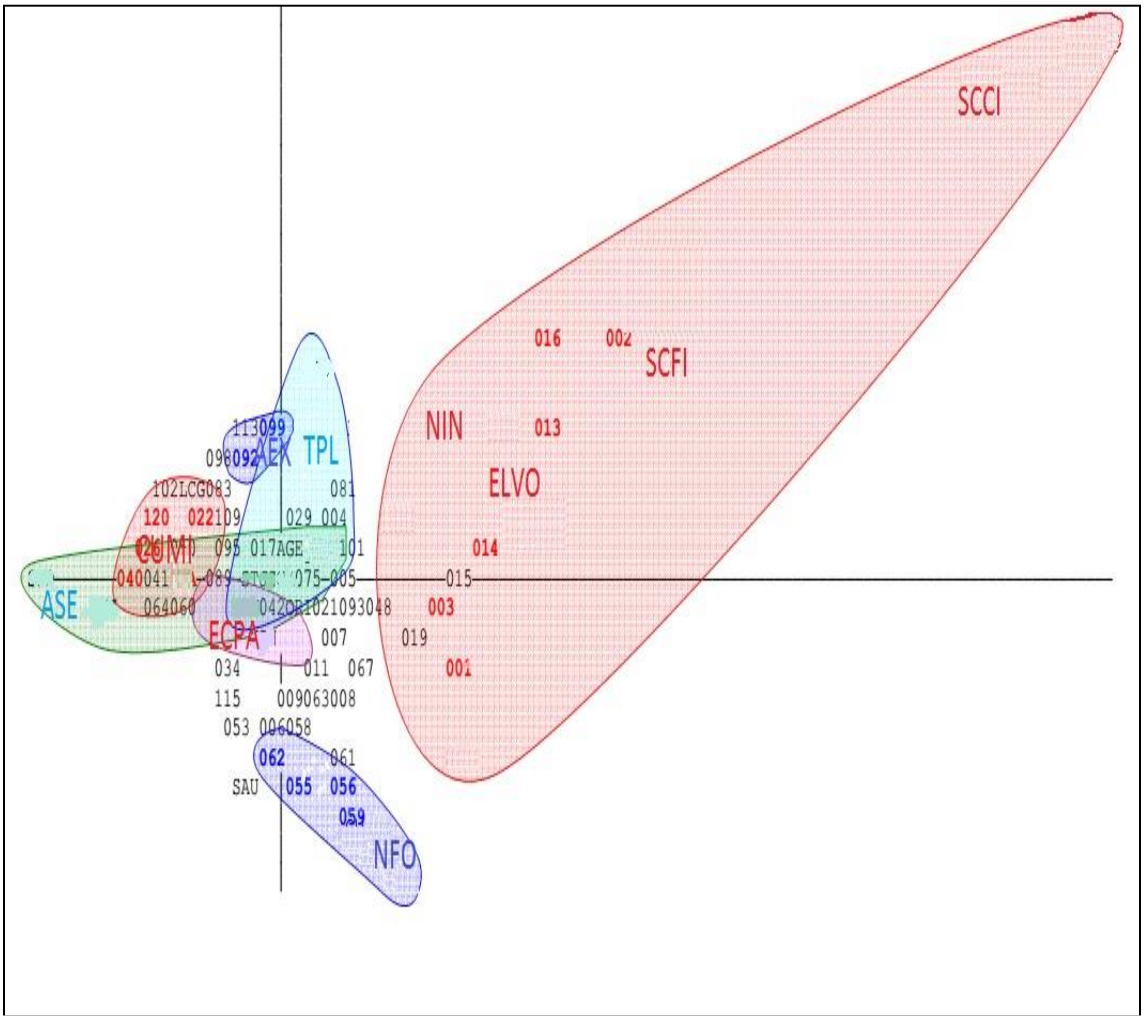

Figure 3. AFCS of Technical Expertise and Equipment (Simultaneous Representation of Observations and Variables)

Analytical Approach to Technicality and Equipment in Agroforestry

3.3.1 Preliminary Project Studies

In 70% of the agroforestry operations, preliminary project studies were conducted primarily to secure subsidies from agricultural conversion programs, especially focused on arboriculture. These programs provided technical guides and led to awareness days organized by agricultural services and local institutes in Djelfa. However, only 30% of operators recognize the importance of integrating fruit tree and forest tree cultivation with sheep farming. This indicator highlights the increasing interest in agroforestry projects, particularly since 2002 in the Senalba Chergui area, supported by the National Fund for Agricultural Regulation and Development (FNRDA) and private consulting firms, indicating gradual adaptation to regulatory and technical frameworks.

3.3.2 Visits by Agricultural Extension Delegates

Visits by agricultural extension delegates were frequent during spring for 90% of the operations but absent for 10%. These visits were often linked to product suppliers, such as those providing inputs for arboriculture and animal healthcare. Training sessions are held for arboriculture, yet the delegates do not always inform operators. This indicates that agroforestry topics should be more integrated into extension programs, as agroforestry remains a crucial agricultural component in Djelfa. The operators benefit from various outreach activities like fairs, expos, and campaigns.

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3.3.3 Frequency of Visits
The frequency of agricultural extension visits is deemed essential for extensive agroforestry operations, requiring ongoing monitoring throughout the agricultural season. The technical demands of arboriculture require active engagement from extension agents, but only 37.5% find these visits frequent enough, with 60% reporting that visits are rare, especially during peak seasons such as summer and fall, and absent in winter. This suggests that systematic support is lacking when most needed. Extension services are supported by demonstration guides, contact farmer guides, methodological handbooks, and monitoring tools, all backed by detailed reports.

3.3.4 Topics of Agricultural Extension
For 55% of operators, agricultural extension topics focused on phytosanitary protection, while 30% involved data collection by agricultural services, the Steppe High Commission, and the forestry department. A smaller proportion (10%) dealt with harvesting and growth monitoring. The need for specialized sessions in agroforestry was noted, and measures were emphasized to enhance extension effectiveness, ensuring that programs address local production needs.

3.3.5 Farmers' Assessment of Agricultural Advice
A majority (82.5%) of farmers felt that the technical advice received was inadequate. While 10% found it satisfactory, another 7.5% rated the sessions as moderately effective. This highlights the urgent need for improved agricultural advisory services to boost farmers' understanding of forest protection, public health, and sustainable farming practices.

3.3.6 Farmers' Visits to Agroforestry Support Structures
Over half (52.5%) of farmers do not actively seek out support from technical structures unless in emergencies. Only 17.25% showed no interest in such visits. This indicates a gap in connecting farmers with support networks, suggesting that stronger outreach and educational strategies are essential for the long-term success of agroforestry.

3.3.7 Group Sessions with Farmers
Group sessions were attended by 45% of operators, while 55% did not participate. Group-based and adult learning methods are necessary for practical training. This form of dynamic interaction allows farmers to exchange knowledge and receive targeted advice on best practices for environmental and agricultural health.

3.3.8 Agricultural Advertising via Radio and TV
Agricultural broadcasts were followed by only 35% of farmers, with 65% not engaging, mainly due to broadcasts occurring during working hours. The lack of interactivity and relatable content has limited the social acceptance of these programs, suggesting a need for more practical, audience-specific content.

3.3.9 Peer Advice
A significant 95% of farmers preferred seeking guidance from experienced peers over technical advisors, who were regarded as less precise and practical. This emphasizes the importance of experiential learning but points out that relying solely on peer advice can risk inefficiency and potential financial losses.

3.3.10 Acceptance of Agricultural Advice
Advice acceptance was split into three categories: 35% fully accepted advice, 60% accepted it moderately, and 5% rejected it entirely. The lack of trust between farmers and extension agents requires immediate attention to improve communication and foster a constructive exchange of information.

3.3.11 Preferred Agricultural Advice Topics
Farmers were mostly interested in advice on sheep farming (62.5%), followed by arboriculture and crop management (20%), and general topics (17.5%). This underlines the need for extension programs to align with farmers' primary interests and practical needs.

3.3.12 Source of Agricultural Advice
Farmers preferred advice from peers (45%), diverse sources (35%), and a small 2.5% from extension agents. This shows a preference for practical, on-the-ground guidance and highlights a need for more engaging, result-oriented training rather than theoretical workshops.

3.3.13 Adherence to Technical Guidelines
Seventy percent of farmers followed technical guidelines moderately, 25% did so well, and 5% did not follow them at all. Ensuring simple, clear, and supported guidelines is crucial for effective agroforestry practices that align with local production needs and environmental sustainability.

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3.3.14 Agricultural Equipment
Approximately 45% of farmers lacked sufficient agricultural machinery for soil work, with 37.5% having adequate equipment, but only 17.5% owning machinery like seeders or harvesters. Agroforestry's reliance on biological methods reduces mechanization needs, making the current equipment situation suitable for existing operations.

3.3.15 Equipment Rental
With 75% of farmers renting equipment when needed and only 25% rarely finding the need, equipment availability is not a major limiting factor for agroforestry in Senalba Chergui.

3.3.16 Agricultural Labor
The use of labor varied: 42.5% relied on family labor, mostly inexperienced; 35% used seasonal family labor; and 22.5% had skilled labor. Agroforestry requires technical expertise, particularly for initial setup but can manage with basic labor for maintenance, although specialized tools may be necessary for specific tasks.

3.4 Statistical Approach (MCA) on Technological and Equipment Aspects
The Multiple Correspondence Analysis (MCA) identifies groups of variables and individuals with similar characteristics, visualized on a two-dimensional plane. The total information explained by the axes is the sum of each axis's contribution. In this study, the first two axes together explain 38.8% of the information, while the next two axes explain 24.5%. Hence, only the first two axes are retained for analysis as they account for the most significant portion of the data.

Key Variable Contributions
- **Axis 1**: Positive contributions come from advertising spots on radio and television (SRT) and preferred types of advice (TCP). The negative side includes farmers' judgment of agricultural advice (CAG), indicating a negative perception of these services.
- **Axis 2**: The positive side features variables related to owning work equipment, such as tractors (MTS) and harnessed equipment (MAT). Conversely, the negative side indicates the absence of equipment rental (LOM).
- **Axis 3**: The variable visits by local extension officers (VDC) and topics discussed during extension sessions (SJV), particularly on protection and statistics, contribute positively. The preferred source of advice (SCP) is found on the negative side.
- **Axes 4 and 5**: The presence of project feasibility studies (EPR) strongly contributes positively to both axes, with a single exploitation lacking this study.

Individual Contributions (Exploits)
- **Axis 1**: All represented farms fall on the positive side, marked by participation in advertising (SRT) and shared advice preferences (TCP), but show negative judgment (CAG) regarding agricultural advice.
- **Axis 2**: Farms are concentrated on the positive side, characterized by having their own tractors (MTS) and harnessed equipment (MAT), without equipment rental (LOM).
- **Axis 3**: Most farms appear on the positive side, while some fall on the negative, signifying participation in extension visits (VDC) focusing on specific topics (SJV) but differing in their preferred advice sources (SCP).
- **Axes 4 and 5**: Most farms show a positive contribution, with the distinguishing feature being the presence or absence of a project feasibility study (EPR).

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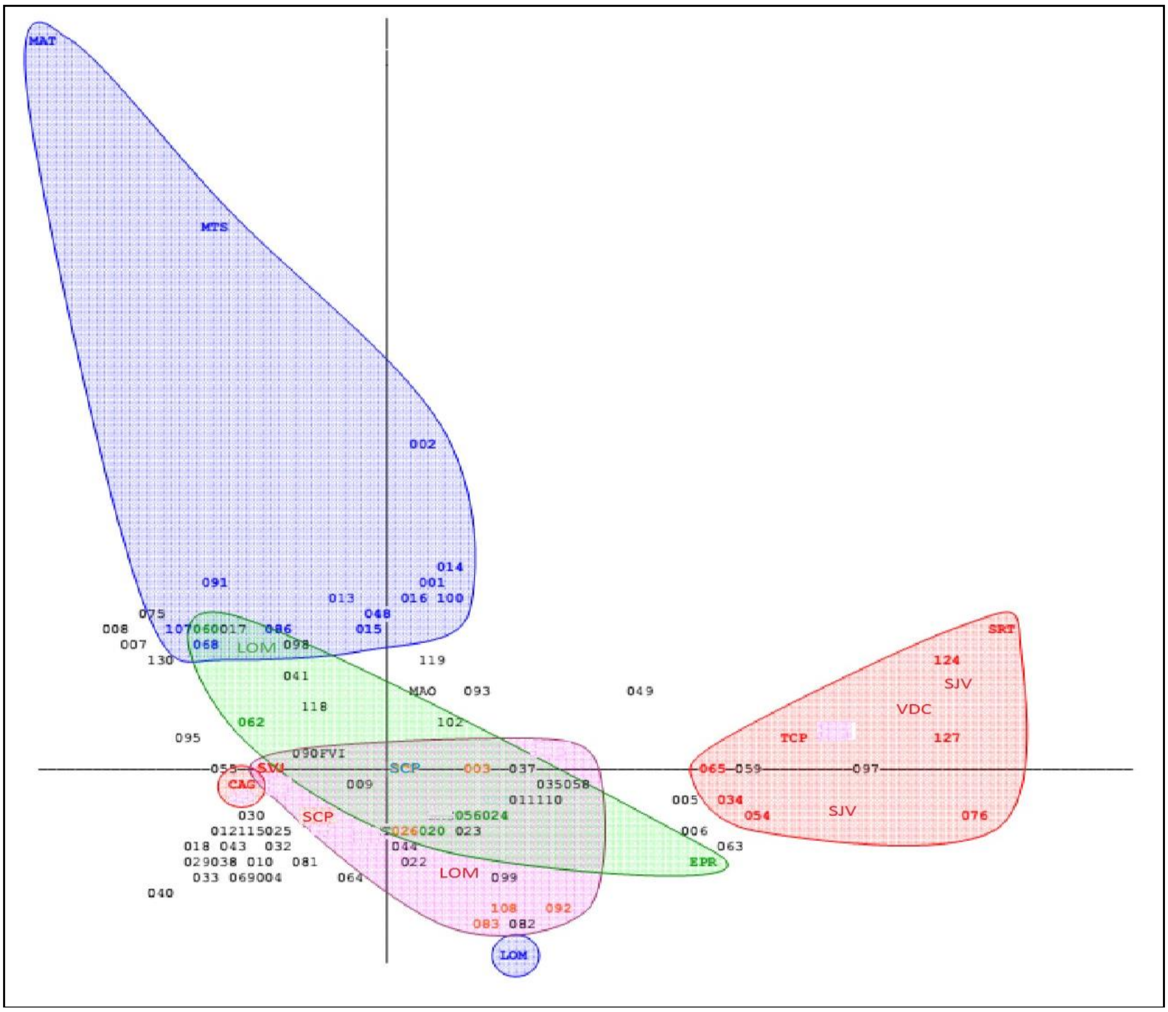

Figure 4. AFCS Technical Expertise and Equipment of the Agroforestry System of Senalba
(Simultaneous Representations of Observations and Variables)

3.5 Analytical Approach to Technical Pathways and Agroforestry Management

3.5.1 Groundwater Depth: The groundwater depth in agroforestry operations is varied, with 47.5% at 4-8 m, 37.5% at 8-12 m, and 15% between 12-25 m. These aquifers, generally of low yield, are used primarily for livestock watering. Deep wells, ranging from 30 to 120 m, supply water for irrigated fruit and forage crops. Monitoring groundwater depth is essential for managing the salinity risks in semi-arid zones. Understanding evaporation dynamics helps quantify water loss, salt deposition, and the overall hydrosaline balance in soils.

3.5.2 Windbreak Types: Two types are present—living and inert. About 70% of farms near forested areas employ inert windbreaks for protecting livestock and facilities, while 30% use living windbreaks made of forest trees. Windbreaks reduce wind speed, with the effective protective zone extending up to 20 times their height on the downwind side. They are especially beneficial for energy conservation in animal shelters.

3.5.3 Water Sources: Most farmers (95%) rely on deep well water for irrigation, with only 5% using groundwater from shallow wells. All farms have water reservoirs; however, 30% report that existing reservoirs are insufficient and plan for expansions. Efficient water use is crucial due to semi-arid conditions and limited rainfall.

3.5.4 Irrigation Systems: The predominant irrigation method (95%) is sprinklers, used for cereal, forage, and vegetable crops, while 5% use flooding techniques. Drip irrigation is utilized by 65% for fruit trees, and 35% use gravity-fed systems. Mixed irrigation techniques are common, with gravity-based methods covering 70% of the area. Managing water scarcity with eco-friendly, effective irrigation systems is critical for sustainable farming in semi-arid regions.

3.5.5 Irrigation Frequency: Typically, irrigation occurs 1-2 times per week in winter and 3-4 times weekly in hot periods. Most farmers do not follow precise irrigation schedules, making efficient water use challenging. Regular irrigation optimizes crop yields and extends tree lifespan.

3.5.6 Drainage Networks: A complete absence of drainage systems (100%) is noted. Drainage is essential for preventing salinity and managing water table rise but is not a priority. Introducing drainage could improve productivity by ensuring consistent yields and facilitating better land management.

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3.5.7 Seed and Plant Quality: The private sector supplies seeds and plants for 60% of operations, while the state provides 40%, mainly for fruit trees and forestry. Most farmers (70%) rate seed quality as good, while 25% find it average, and 5% deem it poor. The agricultural sector includes both traditional, well-adapted local varieties and improved strains that may need further study to evaluate their performance in terms of yield and disease resistance.

3.6 Statistical Approach (AFC) to Technical Pathways and Agroforestry Management

The analysis visualizes variables and farms on a two-dimensional plane, with two axes explaining 33.7% of total variation. Variables such as water resources (REA) and deep well capture (CAF) heavily influence the first axis. The irrigation system (IRR) and seed/plant origin (OSP) contribute to the fourth axis, with drainage (RED) affecting the fifth. Notably, 5% of farms exhibit a strong negative contribution to the second axis due to consistent irrigation practices. On the third axis, 10% have insufficient water storage, while 45% show robust water storage practices, correlated with pesticide use. Absence of drainage (RED) prominently appears on the fourth axis, and for the fifth, the variable "Origin of seeds and plants" is significant on the negative side.

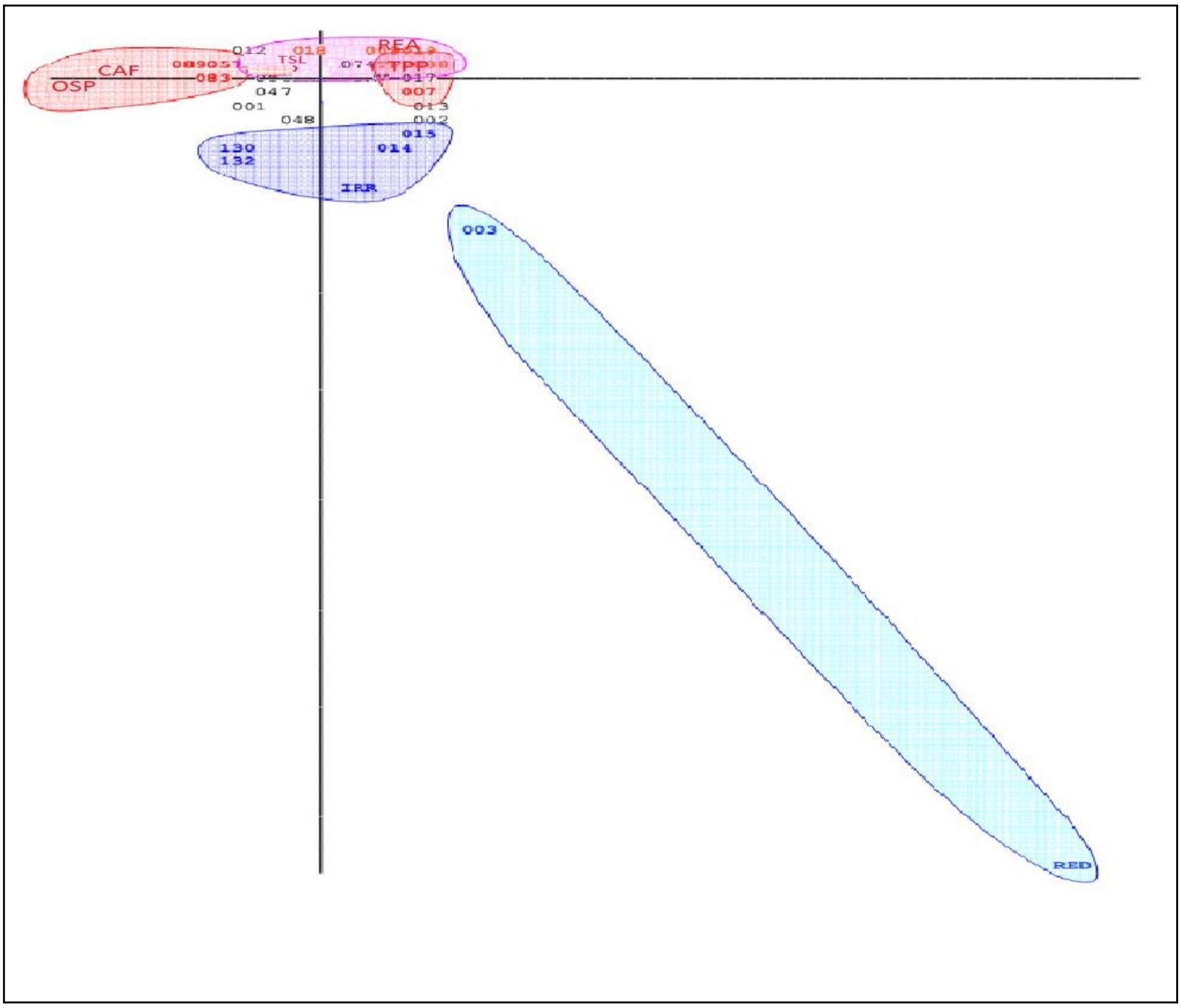

Figure 5. AFCS of Irrigation, Land Management, and the Use of Fertilizers and Phytosanitary Products for the Agroforestry System of Senalba Chergui

3.7 Analytical Approach to Cultural Techniques (Soil Work, Sowing, and Planting)

3.7.1 Soil Work and Sowing

Types of Tillage: Only 7.5% of farmers perform shallow tillage suited for fragile steppe soils, while 70% conduct medium tillage, and 22.5% engage in deep tillage. Agroforestry systems advocate for shallow tillage to mitigate the damage caused by deeper methods, making it the most recommended practice for steppe soils.

Shallow Techniques: Harrowing is employed by 52.5% of farmers, with the remaining 47.5% not using this technique, which is particularly suited for market gardening. Most farmers (97.5%) level the soil before establishing forage and vegetable crops, while 2.5% find this step unnecessary.

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Soil Disinfection: 60% of farmers do not use chemical treatments for soil disinfection, opting instead for solarization (exposing fields to sunlight before sowing). The remaining 40% use both chemical disinfection and solarization for market crops. Agroforestry promotes solarization as a safer and more cost-effective alternative to chemical use, which poses environmental risks.
Sowing and Planting: 67.5% of farmers have a nursery for seed production, while 37.5% rely on exchanges or obtain seedlings from agricultural services or forestry departments. The agroforestry system's sustainability depends on self-sufficiency in seed production. Direct sowing equipment often uses disc-type mechanisms that minimize soil disruption, promoting efficient seed and fertilizer placement in a single pass.
Fertilization: Organic fertilization is practiced once per cropping cycle by 60% of farmers, often combined with a single application of chemical fertilizer. A smaller portion (32.5%) applies fertilization 2-3 times per cycle, while 7.5% limit fertilization to market gardening. Greenhouse operators use chemical fertilizers monthly, with 57.5% applying once a month, 30% twice, and 2.5% three times. Organic fertilizers are primarily sourced from sheep farming (85%), supplemented by neighboring farms (15%). Mineral fertilizers are mostly supplied by the private sector (70%), with the state providing the rest (30%). The integration of organic and mineral fertilizers helps maintain soil fertility and supports increased yields through better crop management and breeding.

3.7.2 Plant Management and Maintenance

Weeding: 97.5% of farmers use manual weeding, while only 2.5% resort to chemical methods.
Pruning: Pruning is done as needed to maintain and improve agroforestry crops.
Crop Rotation: Only 2.5% practice crop rotation, indicating limited use of this beneficial technique.
Phytosanitary Protection: 55% of farmers use insecticides, 30% use both insecticides and fungicides, and 15% use only fungicides. These are predominantly applied to vegetable crops (75%), followed by tree crops (20%), with other crops receiving minimal treatment (5%). 70% of farmers believe phytosanitary measures yield moderate results, 25% report poor results, and only 5% find them effective. The use of chemical products is discouraged due to their environmental impact. The effectiveness varies, with 60% rating them moderately effective, 35% highly effective, and 5% ineffective. Agroforestry practices promote alternatives to chemical use, favoring biological solutions that are cost-effective and environmentally sustainable.

3.8 Statistical Approach (AFC) to Cultural Techniques (Soil Work, Sowing, and Planting)

The analysis identifies groups of variables and individuals with similar characteristics. The first two axes explain 52.8% of the variation, highlighting significant practices in agroforestry. Variables such as organic fertilization (UFO) and soil disinfection (DSO, solarization) contribute to the first axis, while phytosanitary use and sowing practices dominate the second axis. Specific farm characteristics, like the absence of pruning (TTA) and the use of soil disinfection (DSL), define the positive and negative sides of each axis, emphasizing the diversity in agroforestry practices and their impacts.

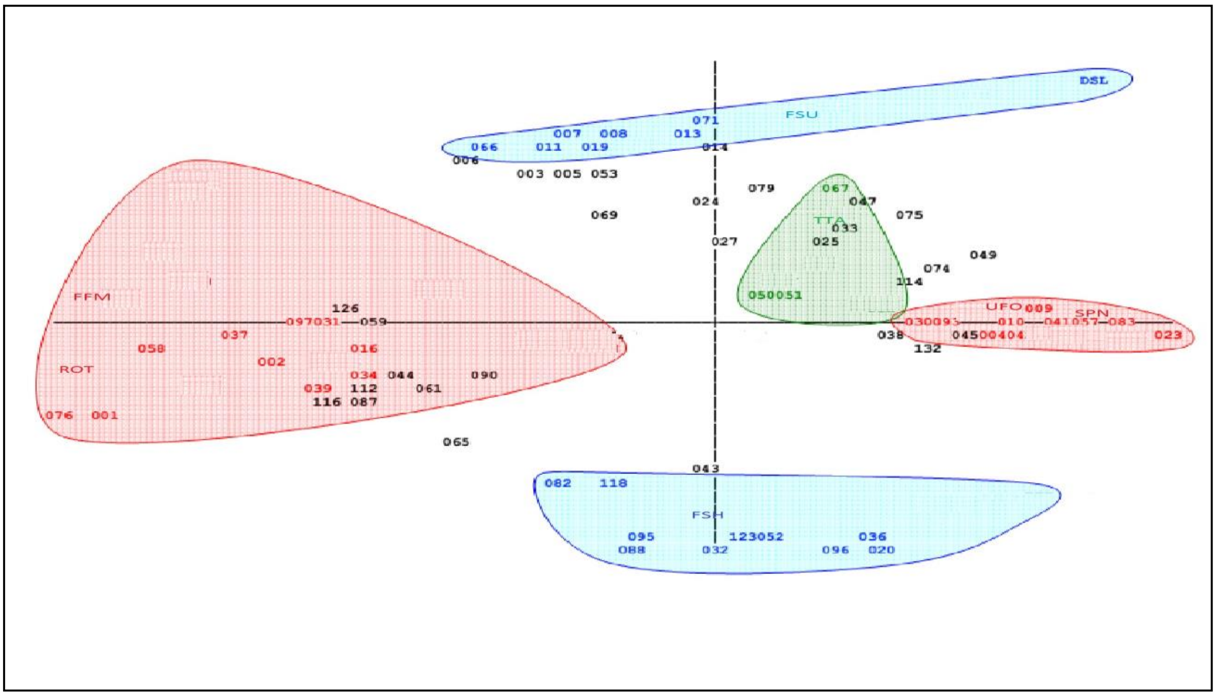

Figure 6. AFCS of Cultural Techniques (Simultaneous Representation of Observations and Variables)

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The development of agroforestry in Senalba Chergui faces several constraints despite its growth in the region. These constraints can be categorized into climatic, edaphic, technical, logistical, and relational challenges.

Constraints and Challenges
Climatic Constraints: The semi-arid climate presents unpredictability, with strong winds during spring damaging fruit blossoms and plants, significant diurnal temperature fluctuations increasing water requirements, and extreme temperatures leading to growth cessation in seedlings or drying out of plants and flowers.
Edaphic Constraints: The lack of soil and mineral studies prior to land allocation has led to disorganized integration of various crops. This ignorance hampers optimal soil use and productivity.

Technical Constraints:
- **Soil Work**: Intensive soil work causes physical and biological damage to the fragile steppe soils.
- **Fertilization**: Issues include overuse or underuse of organic and mineral fertilizers, use of non-decomposed manure, and contamination risks from inadequate handling.
- **Seeds and Planting**: Poor seed quality, limited variety, improper sowing practices, and lack of seedling care and sanitation are prevalent.
- **Irrigation**: Issues include weak water flow, improper usage, and saline water sources.
- **Cultural Operations**: Inadequate weeding, infrequent pruning, high costs of pesticides, and improper application techniques are common. Harvesting practices often damage produce and plants due to poor handling and insufficient storage facilities.

Logistical Constraints: A shortage of skilled labor, inadequate storage, transportation deficiencies, irregular supply of agricultural inputs, and the lack of electrification are significant barriers.
Relational Constraints: These include insufficient state oversight, a mismatch between farmers' challenges and the extension services' focus, unqualified extension agents, and lack of trust between farmers and development institutions. The inefficacy of agricultural associations further compounds the issue.

Perspectives and Strategies
To address these constraints, several strategies are proposed:
- Strengthen and establish windbreaks to mitigate climatic damage.
- Foster farmer associations to enhance access to expert advice and services.
- Ensure systematic disinfection of manure before use.
- Implement rationalized fertilization practices tailored to soil and crop needs.
- Adopt integrated pest management and limit pesticide use.
- Improve transportation access and extend marketable land areas.
- Diversify crops and integrate new agricultural techniques.
- Promote livestock as a dual source of income and organic fertilizer.
- Optimize land use and reduce costs by leveraging family labor.
- Develop agroforestry-related revenue streams, such as eco-tourism, to reinvest in farms.

Table 2.Characteristics, constraints and strategies of the different existing types

Type	Characteristics	Constraints	Strategies
Type 1	• Total farm area: 20-25 ha • Number of sheep: 100-120 head • Cereal cultivation area: < 5 ha • Forage crop area: < 1 ha • Area of fruit and forest trees: 2-6 ha • Generally, education level is intermediate or secondary • Age of the farmer: 20-40 years	• Lack of agricultural extension and extension plan follow-up • Financial constraints • High production input costs • Poor water management • High energy costs • Limited knowledge of farming techniques • Lack of expertise • Family and permanent labor • Absence of a nursery	• Expansion of fruit and forest tree areas • Crop diversification • Trend toward introducing new techniques • Introduction of new crops • Use of creative solutions
Type 2	• Total farm area: > 100 ha • Cereal cultivation area: 10-20 ha • Number of sheep: 80-100 head • Forage crop area: 1-2 ha • Area of fruit and forest trees: 6-8 ha	• Limited knowledge of farming techniques • Rare visits from extension agents • High production input costs • Poor water management • High electricity costs • Lack of expertise • Distance from residence and market	• Comprehensive long-term development strategy, sustainable agroforestry system • Livestock farming as a source of income diversification • Crop diversification • Expansion of vegetable crop areas

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	• Generally, education level is primary or Quranic • Protected vegetable crop area: < 0.16 ha • Age of the farmer: 40-60 years	• Permanent and seasonal labor • Absence of a nursery (plants purchased or direct sowing)	• Acquisition of transportation means • Trend toward introducing new techniques
Type 3	• Total farm area: 20-60 ha • Cereal cultivation area: > 30 ha • Forage crop area: > 16 ha • Protected vegetable crop area: < 0.16 ha • Area of fruit and forest trees: > 12 ha • Generally, education level is primary or Quranic • Age of the farmer: > 60 years	• High electricity costs • Limited knowledge of farming techniques • Lack of relationships between farmers and technical support structures • Limited financial resources • High production input costs • Poor water management • Distance from the market • Mixed labor • Absence of a nursery (plants purchased or direct sowing) • Lack of transportation	• Gradual development • Acquisition of transportation means • Livestock farming as a source of income diversification • Non-bank borrowing • Shift toward introducing new techniques
Type 4	• Total farm area: 3-6 ha • Area of fruit and forest trees: 3-4 ha • No cereal cultivation • No forage crops • Number of sheep: 40-50 head • Protected vegetable crop area: 0.16–0.32 ha • Generally, education level is intermediate or secondary • Age of the farmer: 18-40 years	• High electricity costs • Limited knowledge of farming techniques • Lack of effective and organized agricultural extension • Absence of government subsidies • High input costs • Water scarcity • Poor water management • Wind issues (damaged windbreaks) • Low production • Distance from residence and market • Mixed labor • Presence of a nursery • Lack of transportation	• Space utilization optimization • Cost reduction by using family labor • Non-bank borrowing • Acquisition of transportation means • Seeking non-agricultural income sources
Type 5	• Total farm area: 9-20 ha • Cereal cultivation area: 5-10 ha • Forage crop area: • Number of sheep: 80-100 head • Area of fruit and forest trees: 1-2 ha • Generally, education level is intermediate or secondary • Age of the farmer: 18-40 years	• High electricity costs • Lack of effective and organized agricultural extension • High input costs • Low production • Distance from market • Family and permanent labor • Absence of a nursery • Lack of transportation	• Acquisition of transportation means • Non-bank borrowing • Crop diversification • Seeking non-agricultural income sources • Introduction of new crops
Type 6	• Total farm area: 25-40 ha • Cereal cultivation area: 5-10 ha • Number of sheep: 100-120 head • Forage crop area: 8-16 ha • Area of fruit and forest trees: 4-8 ha • Dryland cereals outside the perimeter • Generally, education level is primary or Quranic • Age of the farmer: 41-60 years	• Rare visits by extension agents • Very low government subsidies and financing difficulties • High input costs • Poor water management • Distance from residence and market • Mixed labor • Absence of a nursery (plants purchased or direct sowing) • Lack of transportation	• Acquisition of transportation means • Livestock farming as a source of income diversification • Crop system diversification • Expansion of vegetable crop areas • Intensification of the cultivated area • Trend toward introducing new techniques

Conclusion

The agroforestry system holds significant economic and ecological value for the agroforestry operations in Senalba Chergui within the Green Dam area of the Algerian steppe. Thoughtful implementation within a coherent integration framework can enhance the agricultural landscape of the region. The outcomes of these practices have been validated by

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field realities and agricultural practices in terms of production, while environmental impacts are becoming increasingly well understood and appear highly positive, gaining broad social acceptability and recognition as a sustainable investment. This analysis of agroforestry operations suggests that the management of agroforestry techniques across one or multiple plots stems from decisions made based on the composition of the agricultural operation. Even in cases, which may be rare, where the technique directly influences the decision, the reasoning is more about optimization within the bioclimatic constraints of the semi-arid region of the Green Dam area of the Algerian steppe, rather than maximizing production capacities in isolation. This decision-making process is influenced by various determining factors such as state incentives under the National Fund for Agricultural Development, the National Agricultural Regulation and Development Fund, the Forestry Development Program, and the Steppe Development Program led by the High Commission of the Steppe.
The agroforestry operator in Senalba Chergui, considered as a decision-making individual, is certainly not the sole actor for the sustainability of agroforestry operations. Alongside the management unit, the local terroir situated within the Green Dam area of the Algerian steppe, with its broader agro-sylvo-pastoral characteristics, forms a secondary level of assessment for the coherence of agroforestry choices. Techniques, regardless of type or historical period, are always derived from social logics and the socio-economic representations of the Ouled Naïl, particularly in relation to sheep farming as a main activity. Thus, answers to questions regarding the effectiveness of agroforestry models should also be sought within this context.
The motivations for adopting agroforestry are often driven by considerations of heritage, economic goals to secure medium-term capital, and environmental benefits, as well as the management of production activity sites integrating fruit and forest trees. This requires an organization of both technical and social rules adapted for agroforestry operators in Senalba Chergui of the Green Dam area of the Algerian steppe. The initial techniques do not appear to be the most difficult to establish, supported by numerous experiments focusing on the profitable cultivation of trees that withstand arid climates and the active limestone content generated by the calcareous rock of steppe soils. These findings allow for even provisional conclusions about methods of implementation, the limitations of various species, and the adaptability of available techniques to drought.
Therefore, the development of agroforestry models, like other agricultural production models in the Algerian steppe, does not solely depend on the direct benefits they provide to farmers individually; the choices they entail must also fit within the social and cultural framework shared by all stakeholders. The issue of the complementarity of practices and rural techniques, already discussed at the level of agroforestry operations in Senalba Chergui of the Green Dam area of the Algerian steppe, must also be considered from the analytical perspective of the farmer and the operation.
The agroforestry experience in Senalba Chergui demonstrates successful elements due to its alignment with the local communities' perceptions of trees in the Green Dam area of the Algerian steppe. Trees are not just seen as wood, even for fuel; more often, they represent territorial marking (gueddal de la terre) and land control, as their planting can enhance the assurance that the agroforestry operator can continue using the land productively within a general forested area.
It is true that for the agroforestry system in Senalba Chergui, where sheep farming is the primary component, several types of production can benefit from the outputs generated by this subsystem within a framework of organic fertilization and the cyclical exchange of outputs and inputs between subsystems (fruit and forest tree cultivation, cereal crops, forage crops, vegetable cultivation, etc.). Agroforestry, therefore, may be the only way to produce the greatest possible amount of agricultural goods without compromising the land's future productive capacity. The food security challenge is such that no risks should be taken that might undermine the outcome: this is where another theoretical advantage of agroforestry comes into play, enhancing the chances of sustainability for these systems.

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