



## Section 3. Environmental economics

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### WHICH EXTENSION METHOD IS ADOPTED TO ENHANCE POTATO PRODUCTIVITY IN TUNISIA?

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#### Abstract

The objective of this work is to analyze the impact of extension services on the productivity of potato production factors. An analysis of the productivity of potato production factors in different farms adopting different extension sources was conducted. To achieve this, a questionnaire survey was carried out on a sample of 123 seasonal potato producers in the governorates of Nabeul, Kairouan, and Sidi Bouzid, with farmers selected randomly.

The results show that a low number of producers use extension services (42%) and rely on the following sources: (i) Regional Agricultural Development Commission (CRDA), (ii) Potato and Artichoke Technical Center (CTPT), and (iii) private advice. The low rate of supervision is mainly explained by the limited availability and number of extension workers. According to the justifications provided by extension workers, the lack of transport due to fuel problems, as well as the insufficient number of extension workers and equipment, contributed to this lack of participation. These logistical barriers may have limited the ability of extension workers to reach more potato producers and deliver extension services effectively.

The results of the analysis, based on the use of the Tanagra tool, show that participation in extension services allows producers to achieve better yields compared to non-participants. Using the Ad hoc model, our study finds that extension has a significantly positive impact on potato yield. This means that the extension service has successfully provided information, knowledge, and practices that have directly contributed to improving the productivity of potato cultivation factors, hence the importance of continuing to invest in extension services to ensure better productivity.

**Keywords:** *Agricultural Extension System, productivity, potato, Tunisia*

## 1. Introduction

Ranking as the third most important food crop globally after rice and wheat, the potato (*Solanum tuberosum* L.) is a fundamental pillar of international food security. According to FAOSTAT (2013) and Devaux et al. (2020), this tuber is cultivated across more than 95 countries, covering approximately 19 million hectares of arable land. With a total global output reaching 378 million tons, production is heavily concentrated in Asia and Europe, led primarily by China, followed by India and Russia. In Tunisia, the potato has transitioned into a staple food of strategic importance, reflected by a significant rise in per capita consumption from 22.6 kg/year in 1990 to over 30 kg/year in 2022 (ON-AGRI, 2022). Currently, this crop accounts for 16% to 19% of the total annual area dedicated to irrigated vegetable production, covering approximately 24,700 hectares. While annual production levels fluctuate, they average 443,000 tons, typically ranging between 350,000 and 460,000 tons. National yields have shown a similar variability, averaging 16 t/ha over time, with recent figures reaching approximately 18 t/ha in 2020.

Despite this evolution, the Tunisian potato sector faces multi-dimensional challenges that hinder its full potential. Structurally, the industry is characterized by a complex, non-institutionalized network of diverse stakeholders, which complicates coordinated management. Environmental factors, particularly bioclimatic diversity and significant interannual and seasonal fluctuations in cultivated areas, further destabilize production. Critically, Tunisia's average yield remains low in comparison to both regional and international benchmarks. While Tunisia averages 16–18 t/ha, neighboring North African countries report higher productivity, such as Algeria (25 t/ha), Egypt (26 t/ha), and Morocco (28 t/ha), while European producers like Spain (33 t/ha) and France (48 t/ha) achieve significantly higher outputs. This performance gap is further evidenced by the internal yield disparity among Tunisian producers, where high-performing seasonal crops reach 30 to 45 t/ha, highlighting a substantial margin for technical and agronomic improvement. The stagnation and uncertainty within this sector are driven by a convergence of technical, socio-economic,

and environmental constraints. Technical limitations, including the slow adoption of modern technologies, sub-optimal agricultural practices, and a disconnect between research findings and field extension methods, directly impact efficiency. These are compounded by socio-economic barriers such as the varying technical proficiency of producers, fragmented organizational structures, limited access to credit, and volatile market prices for both inputs and final produce. Furthermore, structural issues, notably the small size of family farms, impede economies of scale. Finally, the increasing frequency of climatic hazards and the broader impacts of climate change introduce significant interannual variability in productivity. These fluctuating indicators create a precarious environment for farmers, necessitating the development of resilient strategies to ensure the sustainability and profitability of the potato value chain in Tunisia.

Beyond technical and environmental barriers, the agricultural sector is increasingly defined by systemic uncertainty. Biotic stresses, including the evolution of resistant pathogens, pests, and invasive weeds, continuously challenge existing control protocols. Simultaneously, climate change acts as a risk multiplier, shifting precipitation patterns and increasing the frequency of thermal stress and extreme weather events. To mitigate these threats and ensure food security, it is imperative to transition toward adaptive management strategies that foster sustainable yield intensification. In this context, addressing the downward pressure on agricultural productivity has become a research priority, particularly as farmers navigate a landscape shaped by rapid socio-economic and environmental mutations.

A critical lever for revitalizing the potato sector lies in the efficacy of agricultural extension services. By bridging the gap between scientific innovation and field application, extension services facilitate the dissemination of technical knowledge, optimized inputs, and resilient technologies to rural communities. While the scientific community has identified diverse technical and institutional pathways to enhance productivity, the practical impact of these methods depends heavily on the communication channels used to reach the end-user. Consequently, this study

examines the interface between extension services and potato cultivation, focusing on the mechanisms of information transfer and the barriers to adoption.

The overarching aim of this research is to investigate how the integration of agricultural extension services shapes potato productivity within the Tunisian context. To achieve this, the study seeks to elucidate the socio-economic and structural drivers that govern a producer's decision to adopt these services, thereby providing a robust, evidence-based framework for the sustainable enhancement of the national value chain. Within this scope, the research tests two central hypotheses: first, that active participation in agricultural extension programs correlates significantly with improved potato yields (H1); and second, that the specific pedagogical approach – ranging from individualized coaching to collective group training – plays a decisive role in optimizing resource management efficiency and overall farm performance (H2).

## **2. Materials and methods.**

### **Agricultural Extension Methods used**

#### **2.1. Mass Extension Method**

Mass agricultural extension is an approach aimed at disseminating agricultural knowledge on a large scale, reaching a wide number of farmers and stakeholders within the agricultural sector. Its primary objective is to maximize impact in terms of improving agricultural practices and enhancing productivity.

This method relies on various communication tools to transmit information, including brochures, leaflets, posters, radio, television, websites, as well as text messages (SMS) and voice messages delivered via mobile phones. The main characteristic of this approach lies in the dissemination of standardized, simple, and low-cost information, enabling broad geographic and social coverage. However, this method offers limited direct interaction with farmers and only marginally considers local specificities.

#### **2.2. On-Farm Demonstration**

On-farm demonstration is a widely used agricultural extension method designed to show farmers how to apply new agricultural techniques or technologies directly in field conditions. This approach allows farmers to observe the concrete benefits and tangible

results of recommended practices, thereby facilitating experiential learning.

By providing hands-on experience, on-farm demonstrations enhance farmers' technical skills and promote the rapid and effective adoption of agricultural innovations. By making the benefits of improved practices visible, this method significantly contributes to increased yields, improved sustainability, and enhanced resilience of agricultural production systems in the face of environmental and economic constraints.

#### **2.3. Approaches to Agricultural Extension**

Agricultural extension approaches encompass the set of methods and strategies used to disseminate agricultural knowledge, information, and technologies to farmers, taking into account institutional, socio-economic, and environmental contexts.

#### **2.4. Generalist Extension Approach**

The generalist approach to agricultural extension is based on the assumption that agricultural information and techniques exist but are not adequately utilized by farmers. It aims to disseminate a broad range of agricultural knowledge and practices in a comprehensive manner, providing farmers with a general knowledge base that enables informed decision-making across different agricultural domains. The outcomes of this approach are commonly assessed through adoption rates of recommended practices and increases in national agricultural production.

#### **2.5. Training and Visit Approach**

The training and visit (T&V) approach emphasizes regular field visits and structured training sessions delivered by specialists in various agricultural disciplines. It involves the establishment of a predefined schedule for training activities and field visits, fostering close collaboration between researchers, extension agents, and farmers. The effectiveness of this approach is primarily evaluated based on increases in the production of targeted crops or commodities.

#### **2.6. Project-Based Approach**

The project-based approach involves the implementation of specific extension activities within a defined geographical area and over a limited time period, often supported by external funding. Its main objective is to demonstrate agricultural techniques and

methods that can be adopted and sustained by farmers beyond the project's completion. The results of this approach are generally measured through short-term changes observed at the project sites.

**2.7 Participatory Approach**

The participatory approach to agricultural extension is based on the active involvement of farmers in the planning, decision-making, and implementation of extension activities. It acknowledges and values farmers' local knowledge and expertise while promoting mutual learning between extension agents and farmers. This approach enhances ownership, relevance, and long-term sustainability of agricultural innovations.

**2.8. Agricultural Systems Development Approach**

The agricultural systems development approach adopts a holistic and systemic perspective, focusing on integrated and sustainable agricultural development. It aims to improve agricultural practices in a comprehensive manner by considering environmental, economic, and social dimensions. This approach promotes efficient use of natural resources, farm sustainability, food security, resilience to climate change, and

the well-being of farmers and rural communities.

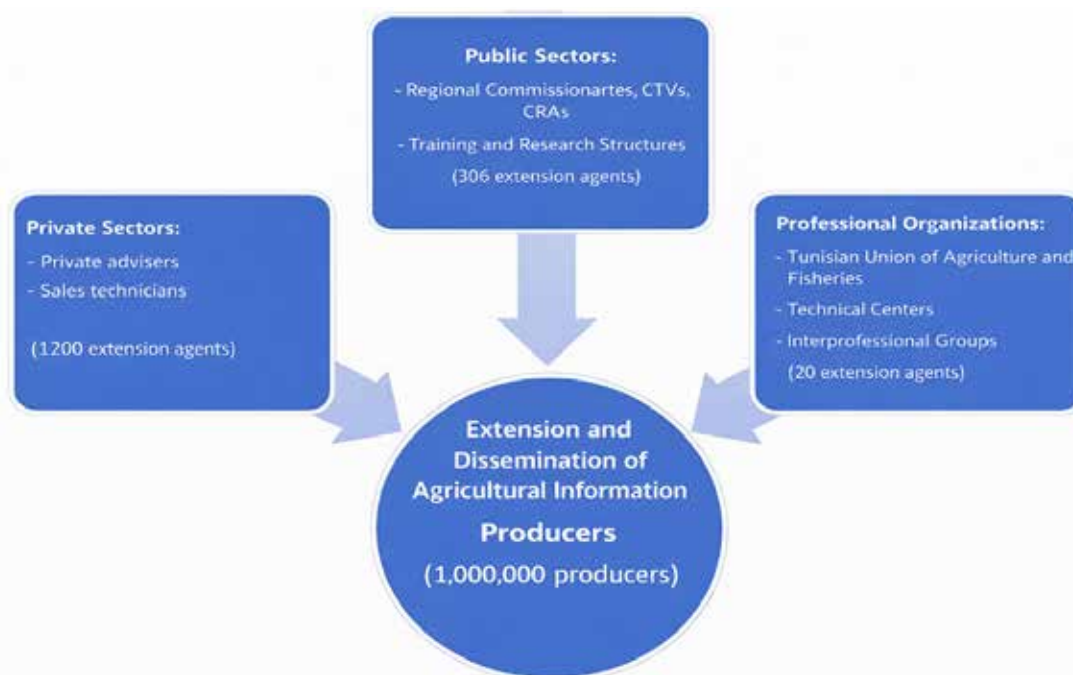
**2.9. Education-Based Institutional Approach**

This approach relies on educational and research institutions that possess the technical knowledge and scientific expertise required to provide extension services to rural populations. Extension activities are generally designed by institutions responsible for developing academic curricula and focus primarily on the transfer of technical knowledge. This centralized, state-driven approach is based on the assumption that necessary techniques and information exist but are underutilized. Its outcomes are measured through adoption rates of recommended practices and increases in national agricultural production.

**2.10. Cost-Sharing Approach**

The cost-sharing approach aims to involve local populations in financing agricultural development programs. It is based on the principle that sharing costs with beneficiaries enhances their commitment and accountability, while improving the relevance and sustainability of extension interventions (Figure.1).

**Figure 1.** Structure of the agricultural extension and knowledge dissemination system in Tunisia potato production



This study is based on an empirical approach to analyze the effect of agricultural

extension services on potato productivity in Tunisia. The methodology combines a field

survey of producers and semi-structured interviews with institutional actors in agricultural extension.

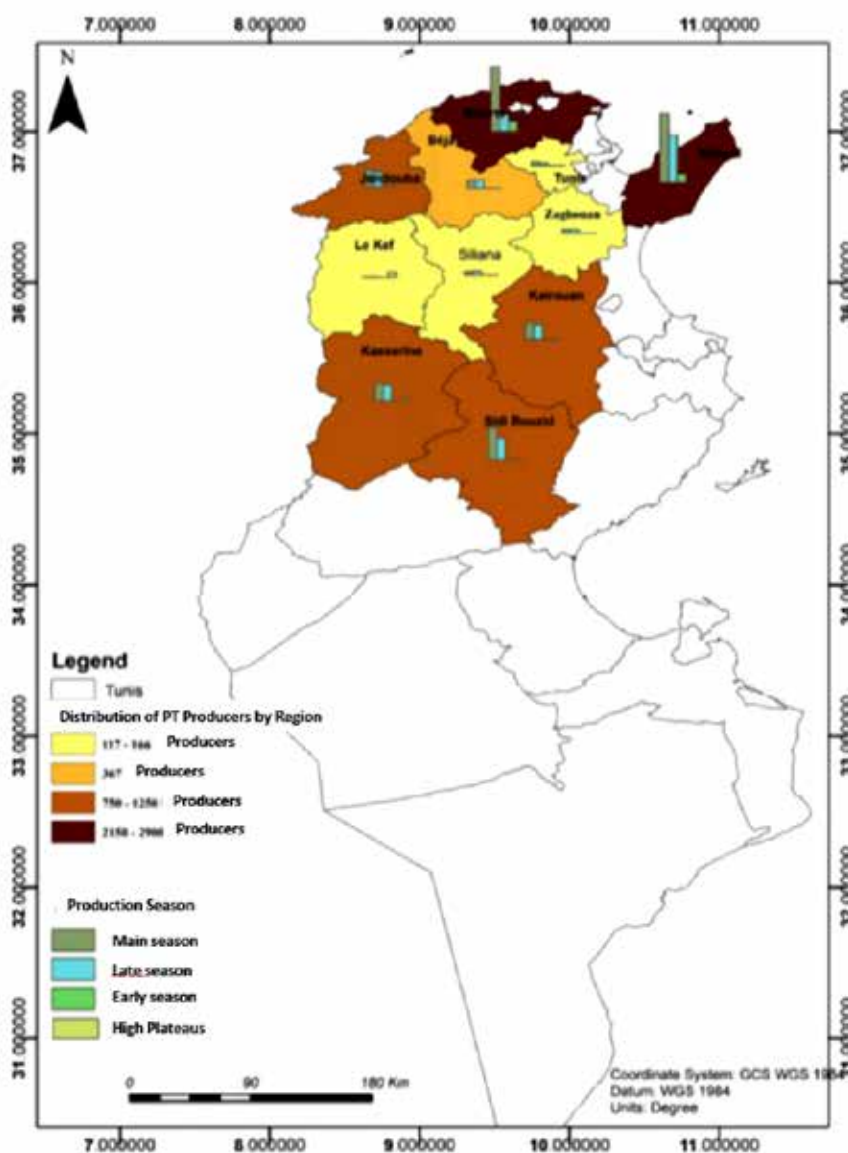
Primary data collection was carried out through the development and administration of a structured questionnaire to potato producers, supplemented by visits and interviews with extension workers from public and professional structures (Agricultural Development Groups (GDA), Regional Agricultural Development Commissions (CRDA), Agricultural Investment Promotion Agency – APIA, etc.). This dual approach allows cross-referencing of pro-

ducers’ perceptions with those of extension agents to obtain a more complete vision of the functioning and effectiveness of extension services.

The field survey took place in December 2022 and January 2023. Interviews with extension workers were conducted based on key concepts related to services offered, available human and material resources, implemented extension strategies, and observed results in terms of innovation adoption and yield improvement.

### 2.2. Characterization of the Study Area

**Figure 2.** Geographic location of the studied governorates (Nabeul, Kairouan, and Sidi Bouzid) within the Tunisian bioclimatic zones



The research was conducted across three strategic governorates that constitute the

primary potato production hubs in Tunisia: Nabeul, Kairouan, and Sidi Bouzid (Figure

2) The selection of these regions is based on their significant economic contribution to the national potato value chain and their distinct agro-ecological profiles. Furthermore, these areas were chosen due to the documented variability in local yields, suggesting substantial potential for productivity optimization through enhanced agricultural extension and improved management practices.

**2.3. Questionnaire Development and Sampling**

The survey questionnaire was structured into four main parts. The first part covers the socio-demographic characteristics of producers, including age, education lev-

el, and agricultural experience. The second part concerns the farm structure, including cultivated area, irrigation sources, cropping systems, and motivations related to potato production. The third part is dedicated to the agricultural extension system. It examines technological information sources mobilized by farmers, their participation in training activities, their membership in professional or non-governmental organizations, as well as their perception and evaluation of received extension services. Finally, the fourth part analyzes the impact of these services on potato yields, to evaluate their effectiveness in the study areas shown in table 1.

**Table 1.** Distribution of surveyed farmers by delegation

Governorate	Delegation	Number of farmers
Nabeul	Korba	40
	El Midaa	25
Kairouan	Chrarda	30
Sidi Bouzid	Souk Jdid	25
	Awled Hafouz	12
<b>Total</b>		<b>132</b>

**2.4. Data Analysis Methods**

After collection, data were coded, processed, and analyzed using statistical software. A descriptive analysis was first carried out to characterize farms, surveyed producers, and mobilized extension services.

To analyze the effect of agricultural extension on productivity, the study relies on the Cobb-Douglas production function, widely used in agricultural productivity analyses. This function expresses the relationship between agricultural production and the various inputs mobilized.

The data were analyzed using Tanagra software, allowing a qualitative and statistical analysis of the effect of extension on yield. Then, Ad-hoc software was used to specifically test the differentiated impact of public and private extension on productivity.

The econometric model estimated is as follows:

$$Y_i = C + \alpha SPDT_i + \beta Vpriv_i + \epsilon Vpub_i + \rho Age_i$$

Where Y denotes yield of potao in the surveyed farmer i,

SPDT<sub>i</sub>: participation in potato extension services,

Vpriv<sub>i</sub>: private extension,

Vpub<sub>i</sub>: public extension,

Age<sub>i</sub>: farmer’s age and C, α, β, ε, ρ the partmeters and constant term.

**3. Results and discussion**

**3.1. Socio-Economic Characterization of Surveyed Farms**

The analysis of farm variables is essential to understand potato production conditions and the technical and organizational choices adopted by farmers. These variables mainly concern land tenure, irrigation sources, as well as crop rotation practices.

**3.1.1. Land Tenure Mode**

Land tenure is a structuring element of the farm, as it directly influences investment decisions, resource management, and the sustainability of production systems. Results show that the majority of surveyed farmers own their land. Indeed, nearly 67.4% of op-

erators have land in full ownership, giving them greater land security and an increased capacity to engage in long-term investments.

### 3.1.2. Potato Irrigation Source

Potato being a crop highly dependent on irrigation, water availability and management are determining factors for farm productivity and sustainability. Survey results reveal that the majority of farmers (78%) obtain irrigation water from private wells. This situation reflects a significant dependence on groundwater resources, often associated with high pumping costs and risks of aquifer over-exploitation.

### 3.1.3. Crop Rotation and Frequency of Potato Return

Crop rotation plays a key role in preserving soil fertility, reducing diseases, and improving agricultural yields. Survey results show that potato constitutes the main activity for nearly 93% of interviewed farmers.

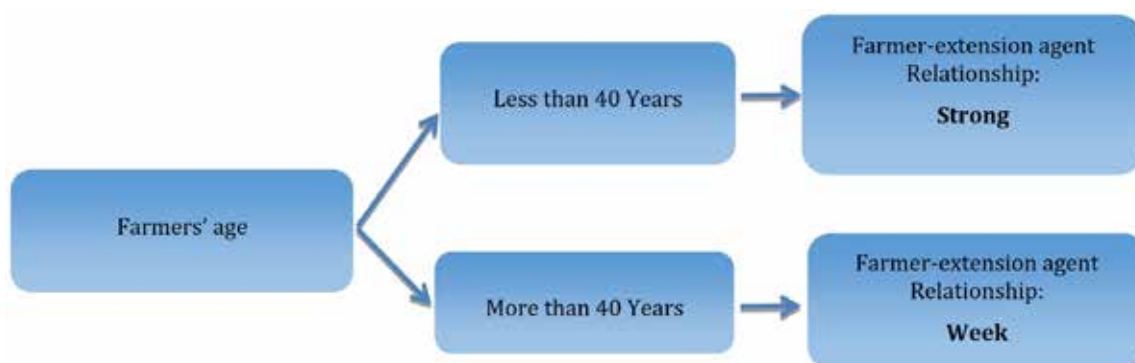
Among them, 57% respect crop rotation by cultivating potatoes on different plots, contributing to better agronomic sustainability.

### 3.2. Farmers' Perception vs. Agricultural Extension System

Figure 2 shows that when farmers are under 40 years of age, the relationship between extension agents and farmers is very strong. This can be explained by the fact that younger farmers actively seek useful information from resource persons, remain attentive to current developments, and place greater trust in new agricultural practices.

In contrast, farmers over 40 years of age tend to exhibit a weaker relationship with extension agents. According to these farmers, this weaker interaction is mainly explained by their professional maturity and the know-how acquired throughout their farming careers.

Figure 2. Effect of farmers' age on the type of relationship farmer-extension agent



Furthermore, the results derived from the decision tree identifying the relationship between farmers and extension agents indicate that when information originates from extension agents affiliated with the GIL and the CRDA, it is considered relevant and is likely to have a positive impact on income improvement.

Conversely, when the relationship between farmers and extension agents is weak, this suggests that farmers are less receptive to extension services and may be considering changing their agricultural activity.

### 3.2.1. Membership in Professional Agricultural Organizations

Analysis of survey results shows that 53% of farmers are members of at least one non-governmental Professional Agricultural Organi-

zation (OPA), such as UTAP, GDA, SMSA, or development associations. Membership in these structures allows farmers to benefit from technical services, organizational support, and better representation of their interests.

### 3.2.2. Specific Training in Potato Cultivation

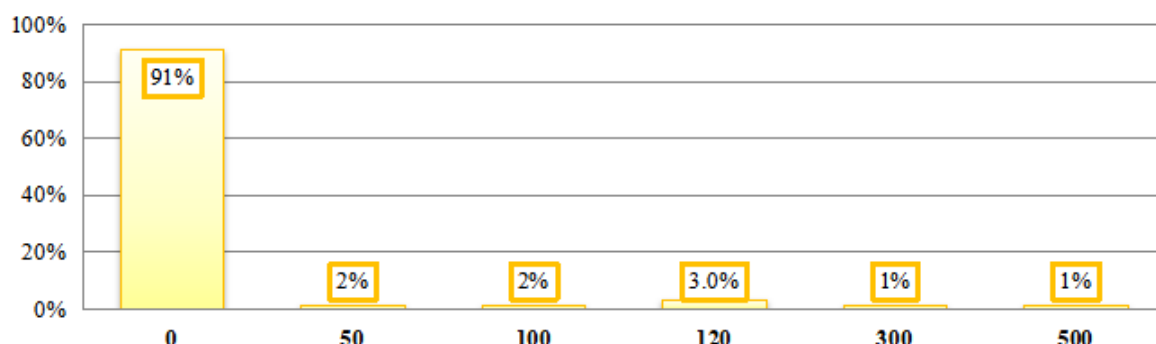
Despite efforts by the Potato and Artichoke Technical Center (CTPTA), results indicate that 70% of farmers have not benefited from specific technical training for this crop. This low participation rate can be explained by the tradition of the activity, lack of information on training programs, and, in some cases, by behavior conditioned to the existence of material incentives.

### 3.2.3. Farmers' Willingness to Pay for Extension

Results show that over 91% of farmers are not willing to pay for agricultural extension services. This position is mainly justified by

the continuous increase in production costs and the perception that the state should cover the extension system (figure 3).

**Figure 3.** *Farmers’ willingness to pay for agricultural extension services*



Source: Our survey, 2022

Figure 3 shows that more than 91% of the interviewed potato farmers are not willing to pay fees for services provided by agricultural extension. Farmers believe that the State should strengthen the extension system, explore alternative approaches adapted to the current context such as irrigation water scarcity and salinity, the emergence of new diseases, early disease detection, digitalized advisory messages, improved storage,

and marketing support motivate extension agents to effectively carry out this essential task, and assume responsibility for financing the entire extension system. Farmers justify this position by the continuously rising cost of production, which makes them financially unable to bear additional expenses related to agricultural extension services.

### 3.3.4. Relevance of Agricultural Extension to Farmers

**Table 2.** *Perceived relevance of agricultural extension*

Level of relevance	Not important at all	Slightly important	Moderately important	Important	Extremely important
Frequency	47	30	14	28	13
Percentage %	35	23	11	21	10

Source: Our survey, 2022

The table 2 highlights farmers’ perceptions of the agricultural extension system. Survey results indicate that only 42% of the surveyed farmers (132 respondents) consider current extension systems to be relevant, with perceived levels ranging from extremely important (10%), important (21%), to moderately important (11%).

These findings indicate a clear need to implement new and more attractive agricultural extension methods. Farmers express a strong demand for change and improvement in existing extension systems. It is therefore essential to take these results into account when redesigning extension approaches, making them more effective, more relevant, and better aligned with farmers’ needs. Furthermore,

farmers’ preferences regarding content, format, and information delivery methods should be considered to enhance the relevance and usefulness of agricultural extension services.

### 3.3. Effect of Extension on Seasonal Potato Yield

Table 3 shows that the effect of private and public extension on potato yield is highly significant. This suggests that extension activities, whether conducted by private or public entities, have a positive impact on potato crop yields. Hence the importance of agricultural extension in improving cultivation practices, adopting effective agricultural techniques, and increasing potato crop yields. These results support the need to continue investing in extension programs to promote sustainable

and productive agriculture. Note that private extension is more important than public extension ( $C=0.186 > 0.143$ ), explained by the fact that private extension workers have

equipment in good condition and technologically more advanced than those of state extension workers, able to move throughout the territory at any time without any problem.

**Table 3.** Estimation model of the effect of extension on seasonal potato yield

Variable	Coefficient	Significance
(Constant)	1.276**	0.00**
Seasonal potato area (SPDT)	0.008	0.222
Private extension (Vpriv)	0.186**	0.002**
Public extension (Vpub)	0.143**	0.001**
Age	-0.001	0.454
R <sup>2</sup> = 18%		

\*\*Significant at 1%

According to the table, it is also noted that area has no effect on potato yield ( $\text{sig}=0.222$ ), confirming Sridhar (2007) who shows through a study on the relationship between farm size and productivity an inverse relationship between farm size and production per hectare.

### 3.4. Effect of Extension Method on Seasonal Potato Productivity

Agricultural extension services significantly influence potato (PDT) yield outcomes, mediated by farmers' socioeconomic characteristics and perceptions. Decision tree analysis conducted using Tanagra software reveals that access to public extension institutions (CRDA, CTPTA) or private consultants is associated with average yields when advisory services are perceived as important or quite important, combined with higher income levels (1,000 to 4,000 TND) and primary to secondary education. Notably, farmers supported by the CRDA achieve superior yields, underscoring the importance of information quality and institutional effectiveness, while CTPTA and private consulting services are linked to intermediate yield outcomes. Conversely, limited engagement with extension services characterized by low perceived relevance, incomes below 1,000TND, and low educational level attainment systematically results in low yields. Interestingly, even in the absence of formal extension services, farmers who perceive advisory support as moderately relevant can attain average yields, suggesting that perception of relevance alone may encourage the adoption

of improved agricultural practices. However, distrust in extension systems often arising from service unavailability or a lack of specialized expertise frequently shifts farm management responsibility entirely to farmers, thereby constraining productivity. Overall, these findings highlight agricultural extension services as a critical lever for enhancing productivity, whose effectiveness depends on socioeconomic conditions, institutional credibility, and farmers' attitudes toward advisory support.

## 4. Conclusions and Policy Recommendations

This study investigated the impact of agricultural extension services on potato productivity in Tunisia. Our findings reveal significant gaps in the current Agricultural Extension System (AES); only 30% of surveyed farmers received specialized potato training, while participation in broader extension programs remained low at 42%, despite 53% of respondents holding memberships in professional agricultural organizations. Extension agents identified critical sectoral deficiencies, specifically a lack of logistical support, transportation, and specialized equipment, which severely constrain their outreach and operational efficiency.

Data analysis via a decision tree model demonstrates that access to extension services is a primary determinant of yield performance, with participants achieving average-to-high yields, whereas non-participants were largely restricted to average-to-low productivity. No-

tably, the model suggests that income levels and formal education are not primary drivers of yield in this context, highlighting the vital role of specialized technical support. Furthermore, the results from the Ad hoc model confirm the central hypothesis: agricultural extension services exert a statistically positive influence on potato yields. This indicates that the dissemination of technical knowledge effectively enhances on-farm performance and optimizes agricultural practices.

Ultimately, this work suggests that the Tunisian AES remains rooted in a conventional “top-down” (research–extensionist–farmer) paradigm. To address modern challenges, a fundamental shift toward a more integrated and multidimensional vision is required.

### **Recommendations for Sectoral Development**

To modernize the potato value chain and enhance the efficiency of the extension system, the following strategic measures are proposed:

- Digitalization of Outreach: Diversify communication channels by integrating social media platforms (e.g., Face-

- book, LinkedIn) to facilitate real-time information sharing and peer-to-peer resource exchange among producers;
- Technological Integration: Develop dedicated mobile agricultural applications to streamline the dissemination of technical protocols, climate alerts, and market data;
- Institutional Synergy: Establish robust public-private partnerships (PPP) to create a coordinated national framework for the exchange of technical innovations and advisory services;
- Fiscal Support: Advocate for targeted state intervention through dedicated budgetary allocations specifically for the modernization of extension infrastructure and logistical capacities;
- Participatory Innovation: Transition toward a “bottom-up” approach where technical innovations emerge from horizontal interactions between researchers, extension agents, and producers, ensuring that research findings are contextually relevant to farmers’ needs.

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