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POLICY AND DEMOGRAPHIC DETERMINANTS INFLUENCING AGRICULTURAL TECHNOLOGY ADOPTION IN JORDAN

Radi A. Tarawneh[1], Khalil Al-Absi[1], Mohammad S. Tarawneh[1], Mawia Osama Al-Mufti[2] and Khaled Al-Najjar[3]*

[1]Department of Economics, Faculty of Agriculture, Jerash University, 26150, Jerash, Jordan;
[2]Agricultural Extension Sector, Ministry of Agriculture, Amman City, Jordan;
[3]General Commission for Scientific Agricultural Research, GCSAR, 12573 Damascus, Syria;
* Corresponding Author: Al-Najjar, K.; Email: khnajj2011@yahoo.com

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ABSTRACT

The importance of this study lies in supporting transition to smart agriculture in Jordan to enhance food security, improve efficient use of natural resources, and address climate change. It aims to analyze impact of demographic, social, and economic characteristics on adoption and sustainability of agricultural technology. The study's findings show that majority of farmers are middle to older-aged and experienced, with a higher percentage of males. Vegetables are the most widely cultivated crop due to their rapid economic return, alongside a relative diversity of other crops. This study indicates that motivations for farming are linked to suitability of crops to local conditions and meeting household needs. Regarding adoption of agricultural technology, the results show that its most significant benefits include easier market access and improved resource and risk management, while high costs, limited access, and a lack of intellectual property protection are the most significant obstacles. The majority of technology users are new adopters. The analyses also revealed that demographic factors significantly influence crop type, farming motivations, and level of technology adoption and sustainability. Strong correlations were found between crop type, farming motivations, perceived benefits of technology, and obstacles to its adoption. The study highlights that adoption of agricultural technology in Jordan is linked to farmers' demographic factors and remains in its developmental stage despite recognition of its economic and environmental benefits. The most significant challenges are high costs and limited accessibility. Therefore, this study recommends policies that support farmers through accessible financing and digital extension services. This transformation is essential for achieving climate-smart agriculture.

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KEYWORDS: Regulation, demographic, Factors, Farming, Innovation, Implementation

1. INTRODUCTION

1.1 Background and Challenges of Adopting Agricultural Technology

Jordanian agriculture faces complex challenges stemming from limited natural resources, high production costs, and climate change, placing pressure on its ability to achieve food security and economic sustainability (Taleb et al., 2013). Despite national efforts within National Agricultural Development Strategy to promote growth and modernize sector through technology adoption, level of adoption remains limited and uneven across regions and social groups (Rola-Rubzen, et al., 2020). This phenomenon is attributed to a range of demographic, social, and economic factors, such as age, experience, gender, and educational level, in addition to weak institutional support and funding directed towards small farmers, high cost of technologies, and a lack of awareness of their economic returns (Cafer, and Rikoon, 2018). Therefore, understanding impact of these factors on technology adoption and its sustainable use is crucial for guiding policies towards precise solutions that enhance productivity and resilience in face of environmental and economic challenges.

1.2 Agricultural Technology Adoption

Jordanian agriculture faces economic, social, and environmental challenges that make adoption of technologies essential for ensuring food security and increasing yields (Abo Znemah et al., 2023). Type and nature of production affect effectiveness of agricultural technology in improving productivity and income, while its use contributes to raising resource efficiency and production quality (Abu harb et al., 2024; Al-Barakeh et al., 2024). Smart and digital technologies play a pivotal role in water and soil management, reducing waste, and enhancing efficiency within frameworks of environmental and social sustainability (Al-Lataifeh et al., 2024; Al-Mithqal et al., 2024). Studies show that adopting technological innovations in sustainable agriculture improves animal health and product quality, which positively influences economic returns (Kaskous et al., 2024; Dayoub et al., 2023, 2024). Role of institutional support, extension services, and agricultural loans in enabling smallholder farmers to use technologies and achieve economic benefits is highlighted (Tarawneh & Najjar, 2023; Tarawneh et al., 2022, 2025). The works concludes that integrating technological innovation, continuous training, and multi-sectoral planning is key to achieving a sustainable digital transformation that balances economic efficiency with conservation of natural resources. However, a research gap persists due to the limited number of studies linking farmers' demographic, socioeconomic, and technological characteristics to their adoption of technology and sustainability practices. Furthermore, there is a lack of analysis of regional and gender disparities, as well as impact of institutional support and national policies on effectiveness of digital transformation.

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1.3 Importance and Objectives

This study is significant in promoting transition to smart and sustainable agriculture in Jordan, contributing to food security, increased efficiency of natural resources, and addressing challenges of climate change. It aims to analyze impact of demographic, social, and economic characteristics, such as age, experience, education, gender, and region, on patterns of agricultural technology adoption and its sustainable use, and to identify obstacles that limit its dissemination. In addition, this study seeks to provide recommendations to support smallholder farmers, rural women, and youth, thereby enhancing productivity, income, and resilience to environmental and economic changes.

2. Materials and METHODS

2.1 Study Design and Tools

This study was designed using a field research methodology to explore impact of farmers' demographic and social characteristics on their agricultural practices and technology adoption. The research relied on quantitative and qualitative data collection tools to ensure a comprehensive analysis of the studied variables. The standardized questionnaire included following main themes: farmers' demographic characteristics (age, gender, experience, educational level, geographic region), agricultural practices (types of crops grown and main motivation behind growing them), and agricultural technology adoption (benefits of using technology, main reasons for not adopting it, and duration of its use).

2.2 Sample Selection and Data Collection

The sample was carefully selected to be representative of Jordanian agricultural sector, including farmers from all regions (northern, central, and southern) to ensure geographical representation and diversity in demographic and social characteristics. Emphasis was placed on smallholder farmers, rural women, and youth to ensure comprehensiveness results.

Data were collected using a questionnaire specifically designed to measure level of agricultural technology adoption. The questionnaire was distributed in field to ensure broad coverage of farmers. The instrument included closed-ended questions to facilitate quantitative analysis, and data were entered into Excel program for validation before statistical analysis.

2.3 Tools Reliability

Reliability of the questionnaire was assessed using Cronbach's alpha coefficient, and results showed high levels for demographic variables (0.71), agricultural practices axis (0.97), and technology adoption (0.98), which enhanced the instrument's reliability and contributed to strengthening credibility.

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2.4 Statistical Analyses

Data were analyzed using SAS (2012) software to interpret demographic and social characteristics of farmers, their agricultural practices, and their level of technology adoption. Descriptive analyses included calculating percentages, means, and standard deviations. Analysis of variance (ANOVA) was used to test differences between various groups and determine their impact on practices and technology adoption, with p-value tests used to identify the most influential variables. Pearson correlation coefficients were estimated to examine relationship between farmers' behavior and their attitudes toward technology adoption.

2.5 Ethical Considerations and Study Limitations

This study adhered to ethical standards, obtaining informed consent from participants, ensuring voluntariness and right to withdraw, and maintaining data confidentiality.

The study was limited to a sample of specific regions, which restricted generalizability of results. Furthermore, the results were influenced by seasonal factors and differences in infrastructure and agricultural services between regions.

3. RESULTS

3.1 Demographic and social characteristics

Table 1 indicates that majority of farmers participating in the study belong to middle to older age group, reflecting accumulated practical experience in agriculture. A significant proportion possess extensive experience exceeding four decades, demonstrating their long-standing involvement in agricultural work and their broad knowledge of its conditions and requirements. Regarding educational attainment, vast majority of farmers hold a bachelor's degree, reflecting a growing trend towards academic education in agriculture. In terms of gender, results show a higher percentage of males than females, consistent with prevailing pattern in Jordan's agricultural sector. Conversely, regional distribution appears relatively even across northern, central, and southern regions, indicating a balanced geographical representation of sample. These results reflect a high degree of statistical significance for most variables, with exception of geographical region, which did not show any statistically significant differences among farmers.

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Table 1. Sociodemographic characteristics of farmers participating

Age/ years	Experience/ years	Education	Region	Gender
Less than 25 15.33%	Less than 10 20.67%	Secondary 0.66%	Northern 33.33%	Male 61.33%
25-34 4.00%	10 to 20 1.33%	Vocational training 0.68%	Middle 33.33%	Female 38.67%
35-44 17.33%	20 to 30 30.67%	Bachelor's Degree 98.00%	Southern 33.33%	-
45-54 62.67%	30 to 40 1.33%	Master's 0.67%	-	-
55 or older 0.67%	Over 40 46.00%	-	-	-
Pr>ChiSq				
0.01	0.01	0.01	0.99	0.01

3.2 Agricultural Practices

Figure 1 shows that vegetables represent the highest percentage of cultivated crops, indicating farmers' heavy reliance on this type of agriculture due to its high economic returns and rapid production cycles. Data shows that cereal, oilseed, and medicinal and aromatic plant crops occupy similar percentages, reflecting a relative diversity in agricultural patterns. Fruit and flower crops represent moderate percentages, while legumes and nuts register the lowest percentages in terms of cultivated area. This distribution indicates farmers' tendency towards crops with faster economic returns, with increasing interest in value-added crops such as medicinal and aromatic plants, which enhances potential for a shift towards diversified and sustainable agriculture.

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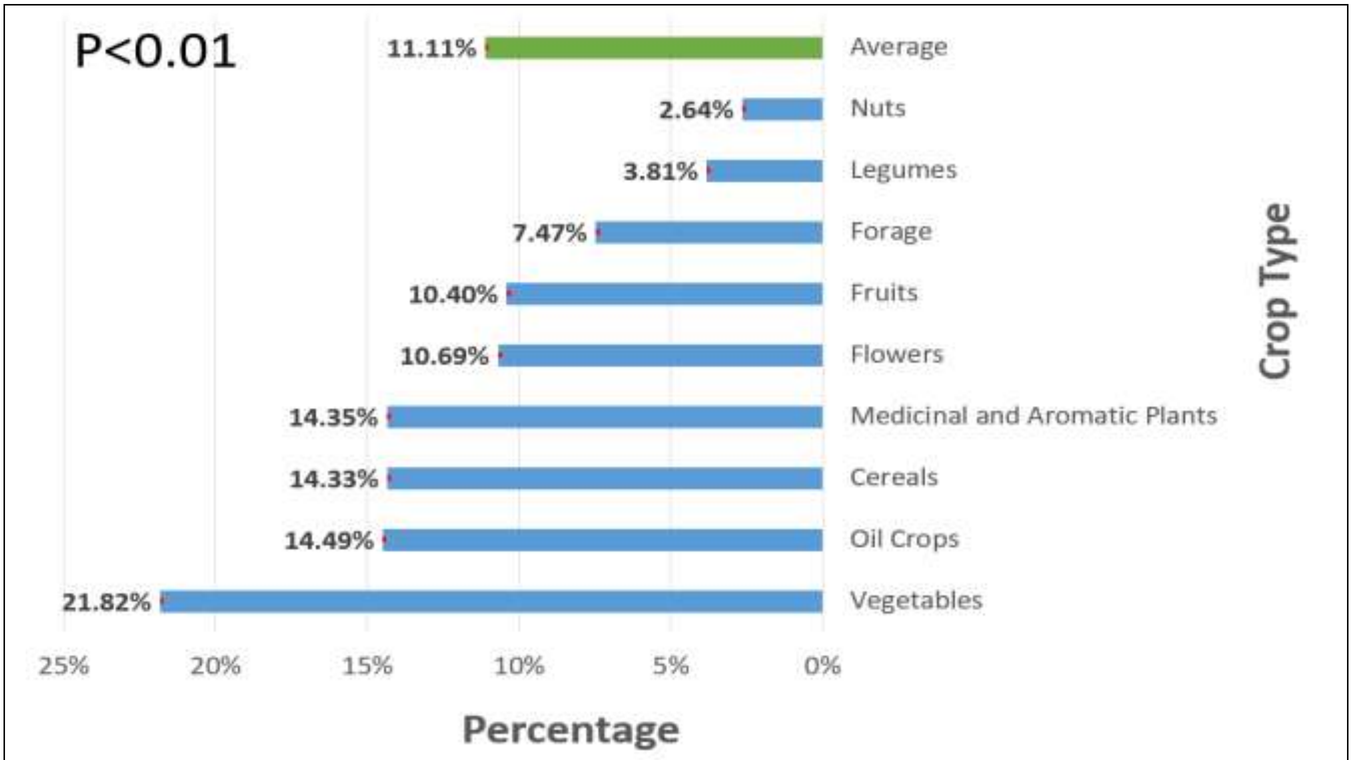

Figure 1: Cultivated crop types

Figure 2 indicates that primary motivation for cultivating crops is their suitability to local conditions, reflecting farmers' awareness of importance of crop compatibility with agricultural environment for achieving stable productivity. Meeting family's food needs is another key incentive, reflecting social and security dimensions of family farming. Other important motivations include industrial purposes, ease of cultivation, and preventing soil erosion, reflecting a growing awareness of importance of sustainable agricultural practices. Some farmers cite environmental considerations such as preserving biodiversity and improving soil fertility, indicating a trend towards integrated ecological agriculture. General, Figure 2 illustrates diversity of motivations for farming, encompassing economic, social, and environmental factors, with statistically significant variations in these motivations among farmers.

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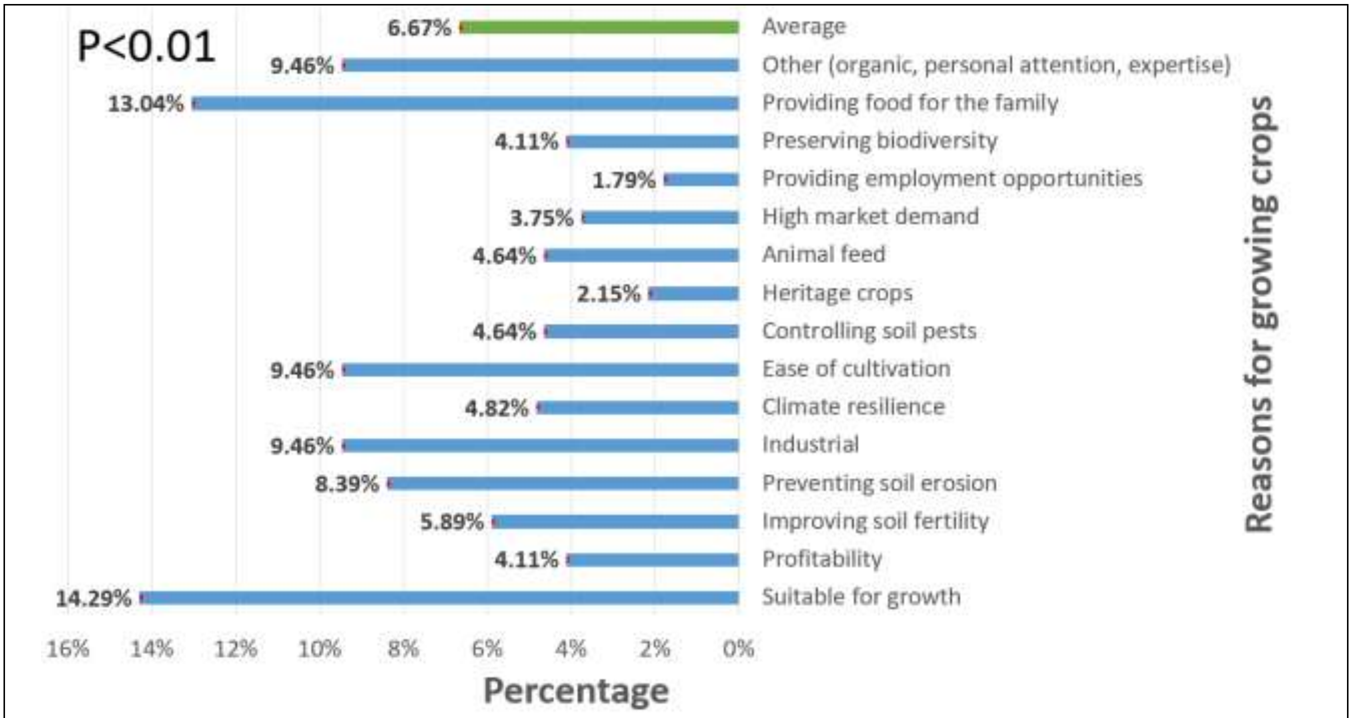

Figure 2: Crop growing reasons

3.3 Adoption of Agricultural Technology

Figure 3 shows the perceived benefits of using technology in agricultural sector. Facilitating market access emerges as the most frequently cited benefit, highlighting central importance of technology in overcoming geographical barriers and boosting trade. Closely following in importance is improved predictability of returns and risks, underscoring technology's role in enabling more informed decision-making, and reducing uncertainty in agricultural operations. Relatedly, improved water resource management and enhanced access to food stand out as significant benefits, reflecting technology's vital contribution to environmental sustainability and food security. Areas such as data analytics and waste reduction are highlighted as key drivers of technology adoption; while equally important are provision of new income opportunities and other benefits, including improved soil health and increased productivity. General, these distributions indicate that the anticipated benefits of agricultural technology span a wide range of dimensions, from improved resource and process efficiency to enhanced economic opportunities and access to information, suggesting a systemic shift towards more and efficient agricultural practices.

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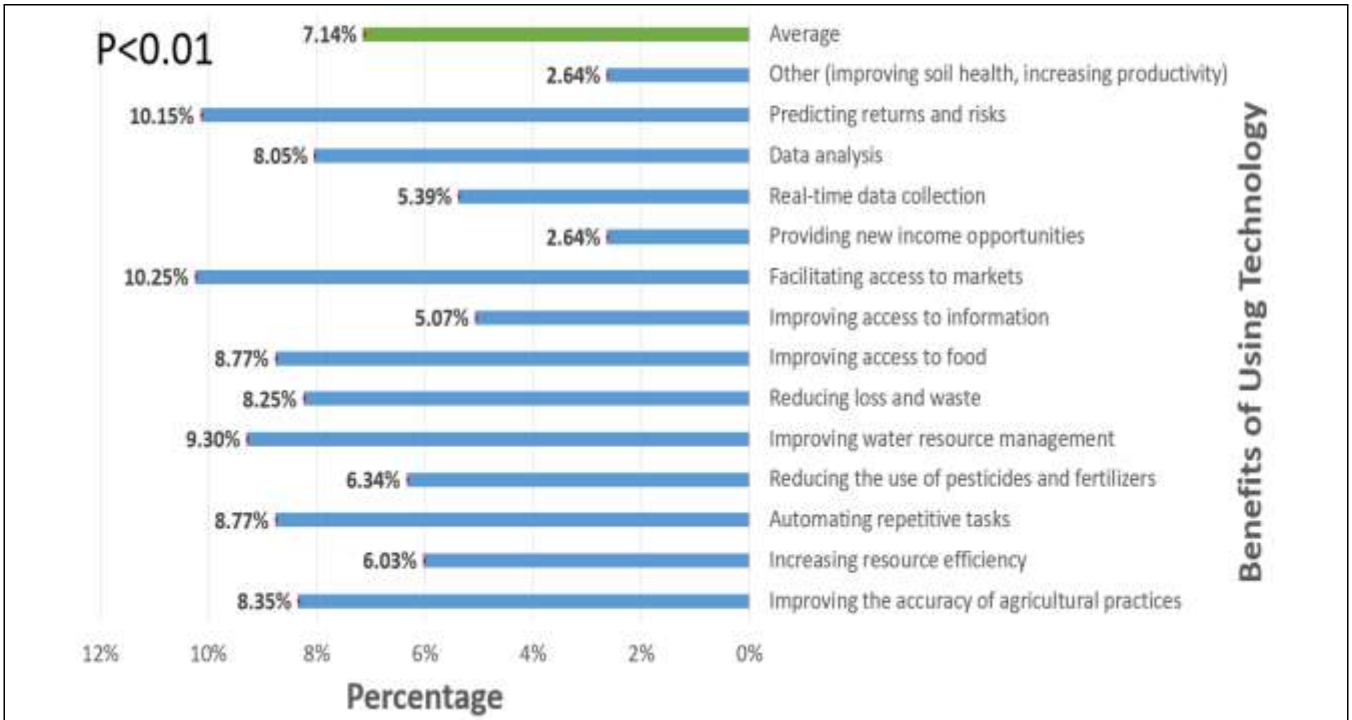

Figure 3: Benefits of using technology

Figure 4 shows main reasons for lack of technology adoption in agricultural sector. Two factors are equally prominent: difficulty accessing technology and a lack of intellectual property protection. This indicates that logistical and legal obstacles represent the biggest challenges farmers face in adopting technological solutions. A group of equally important factors follows, including a lack of social support, the unsuitability of technology to local conditions, and absence of a clear return on investment. This highlights that uncertainties about economic viability and cultural and societal appropriateness play a pivotal role in decision-making process. High cost is a significant challenge, confirming that financial considerations are a barrier to adoption. On the other hand, factors such as technical complexity, lack of knowledge and skills, insufficient investment, regulations and policies, and environmental concerns are present but less prominent than leading factors. Table 4 points to a variety of other reasons, including resistance to change and lack of resources, reflecting multifaceted nature of challenges facing technological transformation process in agriculture.

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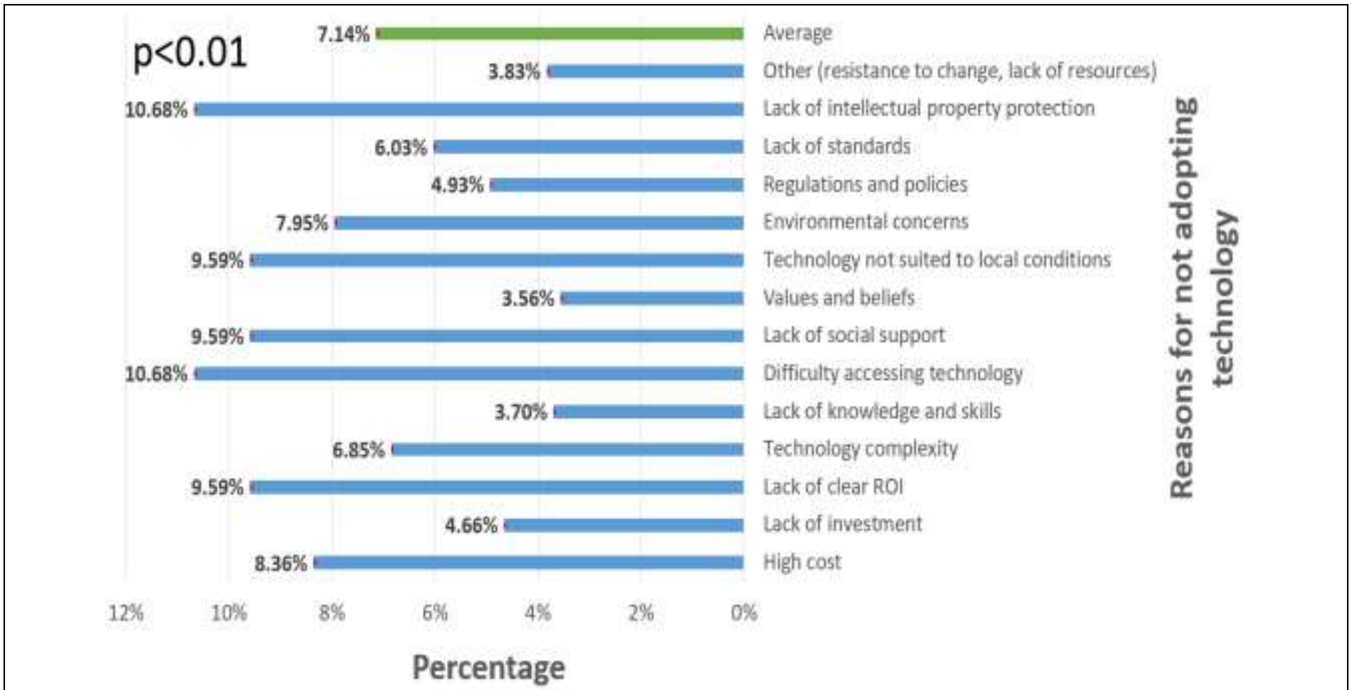

Figure 4: Main reasons for not adopting technology

Figure 5, showing duration of technology adoption in agricultural sector, indicates that majority of farmers adopting technologies are relatively new users. Data shows that vast majority of them began using these tools within one to three years. This high percentage suggests a recent and strong wave of technology adoption in agriculture, reflecting a rapid shift in practices in recent years. In contrast, category of older users, those with five or more years of use, constitutes a small percentage, confirming that widespread technology adoption in this sector is still a relatively recent phenomenon. The proportion of very new users, those with less than one year of use, is significant but considerably smaller than category with one to three years of use. This may indicate that technology begins to gain real and stable acceptance after first year of use. General, these distributions demonstrate that sector is currently experiencing a phase of growth and expansion in adoption of agricultural technologies.

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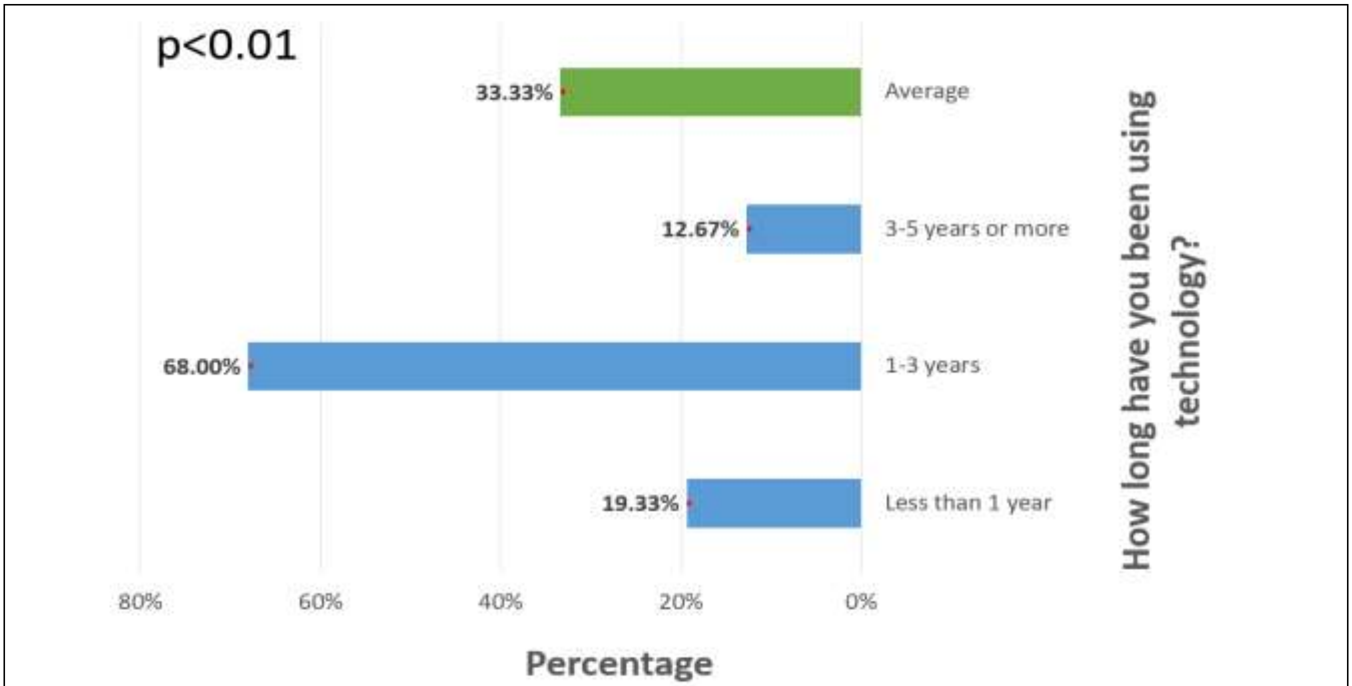

Figure 5: duration of technology use

3.4 The Impact of Demographic and Social Factors

Table 2 shows a significant and varied impact of demographic factors on agricultural practices and technology adoption among farmers. Regarding agricultural practices, farmers' age, gender, region, and experience have statistically significant effects on crop selection, indicating that these demographic factors play a pivotal role in shaping farmers' basic agricultural decisions. Education, however, does not significantly influence crop selection. Concerning reasons for crop selection, age, gender, and experience have a significant impact, while education and region do not. In context of technology adoption, age, education, region, and experience are significantly associated with benefits of technology use, while gender is not. Gender and region, on the other hand, significantly influence reasons for not adopting technology. Data show that age, gender, region and experience are strongly associated with duration of technology use, making demographics key factor for sustained adoption, while impact of education remains limited except in perception of benefits of technology.

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Table 2: ANOVA for Effect of Demographic Factors on Agricultural Practices and Technology Adoption %

Variable		Source	F Value	Pr > F
Agricultural Practices %	Type of crops grown	Age of farmers/ years	3.79	0.01
		Gender	4.19	0.04
		Education	1.06	0.35
		Region	8.21	0.01
		Experience/ years	8.52	0.01
	Reason for growing crops	Age of farmers/ years	8.96	0.01
		Gender	6.51	0.01
		Education	1.86	0.16
		Region	2.30	0.10
		Experience/ years	4.98	0.01
Technology Adoption %	Benefits of using technology	Age of farmers/ years	2.60	0.05
		Gender	1.25	0.26
		Education	3.91	0.02
		Region	4.62	0.01
		Experience/ years	3.49	0.02
	Reasons for not adopting technology	Age of farmers/ years	1.82	0.14
		Gender	8.72	0.01
		Education	0.08	0.92
		Region	3.94	0.02
		Experience/ years	1.12	0.34
	Period of technology use	Age of farmers/ years	39.70	0.01
		Gender	65.85	0.01
		Education	1.82	0.17
		Region	15.85	0.01
		Experience/ years	18.04	0.01

3.5 The Relationship between Agricultural Practices and Technology Adoption

Table 3 illustrates strong, positive, and significant relationships between several variables related to agricultural practices and technology adoption. All correlation coefficients indicate a very strong positive relationship. A close reciprocal relationship is evident between type of crop grown, reason for growing it, perceived benefits of using technology, and reasons for not adopting it, with coefficients ranging from 0.81 to 0.98. This very strong correlation suggests that type of crop farmers choose is closely related to their primary motivation for farming. This motivation, in turn, is strongly related to how they perceive benefits of technology and obstacles that make them hesitant to adopt it, thus warranting further analysis of how these interrelated variables influence agricultural decisions.

Table 3: Pearson correlation between crop type, farming motivations, and technology perception

Variables	Reason for growing crops	Benefits of using technology	Reasons for not adopting technology
Type of crops grown	0.96**	0.81**	0.97**
Reason for growing crops	-	0.97**	0.97**
Benefits of using technology	-	-	0.98**

4. DISCUSSION

4.1 Benefits and obstacles to adopting agricultural technology

The study's findings reveal a clear overlap between perceived benefits of agricultural technology and obstacles hindering its adoption, reflecting a gap between theoretical potential and practical application of agricultural transformation. Farmers seek to improve market access and enhance the predictability of returns and risks to increase economic efficiency through use of technology. However, limited access, high costs, lack of intellectual property protection, and absence of a clear return on investment are the most significant obstacles limiting its adoption, despite farmers' awareness of its impact on water resource management and reduction of losses and waste. Studies indicate that adopting digital agricultural technologies, the Internet of Things, and biotechnology enhances resource sustainability and efficiency, reduces costs, increases yields, and improves quality, particularly among highly knowledgeable farmers (Srivastav & Das, 2025; Limpamont et al., 2024; Geng et al., 2023). Nevertheless, farmers face challenges including farm and ecosystem constraints, weak infrastructure, limited technical capacity, economic constraints, community and regulatory resistance, and incompatibility with certain crops or farming methods. To overcome these obstacles, studies recommend implementing sustainable strategies that include awareness and training, policy support, innovative financial instruments, collaborative platforms, flexible frameworks, and technical consultations before and after adoption, while aligning technology with farmers' needs to ensure effective and sustainable adoption.

4.2 Adoption and its Implications for Technology Sustainability

Data indicates that majority of farmers are new users of agricultural technology (one to three years old), reflecting a recent wave of adoption in response to current challenges and opportunities in agricultural market. While they recognize potential benefits of these technologies, short duration of their use limits their ability to achieve long-term economic returns, given ongoing challenges such as high costs and unclear return on investment. Conversely, decline in 'difficulty accessing technology' barrier reflects improvements in digital infrastructure and agricultural extension services, but it highlights need for supportive policies to ensure sustainability and expansion of this momentum. This aligns with findings of Al-Emran & Griffy-Brown (2023), Rantala et al. (2018), and Wunderlich et al. (2019), who have shown that technology adoption is a crucial factor in achieving sustainability, and that its positive impact depends on awareness, incentives, and institutional support. While innovative adoption enhances economic and developmental dimensions through new models and services (Rantala et al., 2018), it simultaneously contributes to improving resource efficiency and system sustainability (Wunderlich et al., 2019), confirming that technology sustainability requires a combination of incentives, institutional support, and community readiness.

4.3 Agricultural Policies to Promote Technological Sustainability

In light of these findings, future agricultural policies should focus on shifting from incentivizing the initial adoption of agricultural technologies to ensuring their financial and technological sustainability. This can be achieved through establishment of long-term support programs, such as an 'Agricultural Technology Guarantee Fund' which provides low-interest loans with extended grace periods exceeding three years, backed by tax incentives that encourage sustainable agricultural investment. This support should also be linked to specialized field extension programs targeting new farmers to reduce knowledge gaps and enhance operational efficiency, along with development of 'model farms' as applied learning centers that demonstrate direct economic and environmental benefits of technology. These approaches align with findings of Huang and Wang (2023), Molossi et al. (2022), and MacPherson et al. (2022), which emphasize need to align agricultural policies with technological innovation, environmental protection, and social justice. In China, emphasis is on supporting precision agriculture and biotechnology with flexible local policies, while in Brazil, focus is on land management and sustainable livestock production. In digital context, emphasis is on establishing clear legal frameworks and data governance to support transition to smart agriculture. Thus, achieving technological sustainability requires an integrated and forward-looking approach that combines financial support, knowledge empowerment, and institutional regulation to ensure balanced and inclusive agricultural development.

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4.4 Extension Agents and Overseeing Technology Adoption

Agricultural extension agents are central to sustainability and adoption of agricultural technology, as success of digital transformation depends on their technical and organizational capabilities and extent of their institutional support. Thapa et al. (2025) indicated that limited resources and governance hinder effective adoption of digital tools, while Becerra-Encinales et al. (2024) presented IETAMSA model, which integrates scientific knowledge with local wisdom through a collaborative approach that fosters resilience of agricultural extension. Mustapha et al. (2022) demonstrated that information and communication technologies contribute to accelerating transfer of agricultural knowledge and improving efficiency of extension services, calling for empowerment of extension agents and provision of digital infrastructure and supportive policies. Therefore, it is proposed to establish a technical oversight unit within Ministry of Agriculture to coordinate support and monitor performance through indicators such as continuity of technology use, beneficiary satisfaction, and improved economic efficiency, linking rewards to tangible results such as increased productivity and development of rural digital infrastructure to ensure equitable and sustainable access to technology.

4.5 The Impact of Demographic Factors on Technology Adoption

Studies indicate that demographic and social factors clearly influence agricultural technology adoption. Age, experience, and geographic location are linked to level of agricultural practices and duration of technology use, while gender plays a role in determining crop types, farming motivations, and barriers to adoption. This necessitates integrating gender analysis into policy design and developing training and funding programs specifically for women farmers. Education is linked to farmers' understanding of economic value of technology, highlighting importance of awareness programs that explain return on investment and environmental and social benefits. In this context, Khan et al. (2021) demonstrated that farm age, size, location, and level of education and innovation increase likelihood of ICT adoption, while gender and diversity do not appear to have a significant impact. However, farmers' awareness of ICT risks and digital security training are crucial. Young farmers on large farms represent a key segment for technology marketing and adoption, prompting policymakers to advocate for expanding digital infrastructure and internet coverage in remote areas. Curry et al. (2021) emphasize that local values, customs, socio-cultural institutions, and work practices, further complicating technology transfer influences technology adoption. At the same time, Ayalew and Germa (2024) explain that age negatively affects technology adoption in Ethiopia, as older farmers tend to resist risks and adhere to traditional practices, calling for their empowerment through training, information support, and development of local development agencies and communication platforms to promote technology acceptance and understanding of adaptation strategies.

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4.6 Adapting Agricultural Policies to Achieve Technology Adoption

Evidence suggests that successful adoption of agricultural technology is closely linked to design of tailored policies that align with characteristics of farmers, crops, and local environments. The strong correlations between crop type, farming motivations, and reasons for non-adoption highlight importance of a thorough field understanding of specific constraints faced by each farmer group. This understanding should be coupled with integrated technical and financial support packages that connect individual farm objectives with tangible benefits of technology, ensuring the delivery of targeted strategic solutions that promote long-term economic and environmental sustainability. Studies such as Smidt & Jokonya (2021) emphasize need to address economic, political, and social factors within future generations' (AVCs) communities. This includes involving farmers in policy design, building trust, expanding and sustaining digital coverage, and promoting cooperation between government agencies, local organizations, and farmers, to ensure that digital technology is aligned with local needs and has a tangible impact on productivity. Moreover, De Mello et al. (2021) emphasize pivotal role of medium-sized enterprises in Brazil in promoting adoption of agricultural technology through incentives, implementation monitoring, training support, and use of specialized tools such as credit and risk management, contributing to development of farmers' capacities and farming methods. Similarly, a study by Rodenburg et al. (2020) demonstrates that adapting agricultural policies in sub-Saharan Africa to integrated agricultural technologies requires encouraging farmers to test practices individually and collectively, and to share experiences to build flexible strategies that enhance productivity, intensify farming safely, and improve livelihoods, with a focus on aligning policies to support technology adoption according to local needs.

5. CONCLUSIONS

This study demonstrates that adoption of agricultural technology in Jordan is crucial for achieving food security and enhancing economic and environmental sustainability of agricultural sector. The findings indicate that demographic, socioeconomic, and other factors, including age, experience, education, gender, and geographic region, play a pivotal role in patterns of technology adoption and its sustainability. Despite numerous benefits of modern technologies in improving productivity, managing resources, and reducing waste, significant challenges remain, including limited access to technology, high investment costs, and a lack of institutional support and targeted financing. Therefore, design of targeted guidance and financing policies, development of effective training and field programs, and strengthening of legal and regulatory framework to support innovation and protect intellectual property are of paramount importance. Focusing on these integrated interventions will ensure technology adoption into sustainable practices, contributing to increased productivity, improved incomes, and empowerment of smallholder farmers, rural women, and youth. This, in turn, will enhance resilience of Jordanian agricultural sector to future environmental, economic, and climate challenges.

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Conflict of Interest

The authors have no conflicts that affect this research.

Ethical considerations

The research was conducted in accordance with approved ethical standards, after obtaining informed consent from the participants, while ensuring complete voluntariness and confidentiality in data collection and its use for purely scientific purposes.

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