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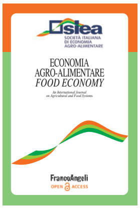

Uncovering the Determinants of the Transition to Digital Agriculture: A Survey-Based Tobit Analysis

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Abstract

This study examines the state of digital agriculture in the Republic of Armenia, a sector characterized by small farm sizes, extensive production models, and limited financial capacity. Using a stratified sample of 400 farms, the research assesses the extent of digital technology adoption, key obstacles, and the determinants of digital penetration. Descriptive findings reveal low adoption rates across most digital tools, driven by high costs, limited awareness, insufficient digital literacy, and skepticism toward digital practices. To provide a more rigorous empirical assessment, a Tobit regression model was applied. The results show that all included variables significantly influence digital adoption, with farm size exerting the strongest positive effect, underscoring the importance of economies of scale. Education, income, production orientation, production model, and age also significantly shape adoption likelihood. The combined descriptive and econometric evidence indicates that the discussed digital gap is largely rooted in structural limitations, particularly the prevalence of very small farms. The study concludes by recommending targeted policies (land consolidation, financial assistance, and farmer training) to support a more modern, efficient, and digitally integrated agricultural sector.

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Introduction

Agriculture is undergoing a significant transformation driven by digital technologies. As the global population grows, the demand for efficient and sustainable food production intensifies. Digitalization presents an opportunity to address these challenges by improving farming practices and resource management.

These issues are highly relevant for the Republic of Armenia (RA). Agriculture is one of the indisputably important sectors of the Armenian economy, which provides the food security of the country and provides employment for the rural population (Asatryan *et al.*, 2022). According to official data for 2022, agriculture provides 10.4% of the GDP, the share of food products in the export volume is 23.9%, and 68.7% of the total area of Armenia is agricultural land. In the conditions of the 4^{th} industrial revolution, the digital transformation of Armenian agriculture can mitigate the issues of productivity, efficiency, and sustainability of agriculture collectively bringing to the provision of Food security (Manucharyan, 2021). Despite ongoing government efforts (particularly the adoption of the "2023-2026 Food Security Development Strategy") Armenia continues to face significant challenges in achieving self-sufficiency in essential food products (Asatryan *et al.*, 2025), underscoring the need for further agricultural development to strengthen national food security. Taking into account all these issues this paper examines the digitalization of agriculture in RA by addressing the following research questions:

- What is the current state and level of digitalization in the agricultural sector?
- To what extent has digital penetration progressed within Armenian agriculture?
- What are the principal obstacles and opportunities shaping the transition toward digital agriculture?
- Which farm-level determinants influence the digital transformation of farms?

The aim of this paper is the provide a comprehensive study of the digitalization of Armenian agriculture and directions of future development.

1. Literature Review

1.1. *Defining Digital Agriculture*

As the 4^{th} industrial revolution is in full swing digitalization is transforming the traditional landscape of national economics by penetrating

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various digital achievements of digital technologies into all the economic sectors. In this regard, agriculture is no exception. Digital agriculture, also referred to as smart farming or precision agriculture, integrates advanced digital technologies into agricultural practices to enhance productivity and efficiency of production. Digital agriculture encompasses a broad range of technologies, including the Internet of Things (IoT), big data, artificial intelligence (AI), drones, robotics, etc. As Wolfert *et al.* (2017) state in their study, digital agriculture involves the integration of advanced technologies in agricultural practices, enabling farmers to gather and analyze vast amounts of data to improve crop yields and resource management. Zhang *et al.* (2019) emphasize that digital agriculture relies on data analytics to inform farming decisions, which can lead to improved efficiency and reduced environmental impact. The Food and Agriculture Organization (FAO, 2021) highlights that digital agriculture not only enhances productivity but also promotes sustainable farming practices by minimizing waste and optimizing resource use. Precision agriculture, a critical component of digital agriculture, uses GPS technologies to manage field variability in crops, leading to targeted interventions that enhance yield at the same time reducing inputs, which leads to an increase in productivity and efficiency (Gebbers and Adamchuk, 2010). So, adopting digital technologies in agriculture can lead to increased profitability and efficiency for farmers through better crop management and reduced operational costs.

Digitalization in agriculture is reshaping farming practices, making them more efficient, sustainable, and responsive to global challenges. The significance and relevance of digitalization in contemporary agriculture is manifested in the following benefits:

1. Digital technologies enhance agricultural productivity. For example, precision agriculture practices, such as the implementation of sensors and satellite imagery, allow farmers to monitor crop health, soil conditions, and weather patterns in real-time. It brings an increase in yields by optimizing inputs like irrigation water, fertilizers, and pesticides, leading to better resource management (Jansson *et al.* 2019).
2. Digital agriculture includes data collection and analysis, allowing farmers to make informed decisions. Zhang *et al.* (2019) discuss how big data analytics in agriculture allows for better forecasting and management of crops, helping farmers respond quickly to challenges.
3. The use of digital technologies can lead to cost reduction and increased profitability in agriculture. By optimizing operations and minimizing inputs, digital agriculture can enhance the economic performance of farms (Geng *et al.*, 2024).
4. Agriculture digitalization promotes sustainable agricultural practices by enabling farmers to use resources more efficiently. Data-driven decision-

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making helps to minimize waste and reduce the environmental impact of farming. Digital tools can enhance sustainable practices by facilitating better resource allocation and reducing emissions. (Hrustek, 2020).

1.2. *Key Technologies in Digital Agriculture*

Digital technologies are transforming agriculture, enhancing productivity, sustainability, and efficiency. This review explores several key technologies, including precision agriculture, the Internet of Things (IoT), drones, big data analytics, and blockchain.

1. Precision Agriculture: Precision agriculture utilizes e.g. GPS, sensors, and data analytics to optimize field-level management. Farmers can make informed decisions regarding planting, watering, and harvesting, leading to increased yields and reduced waste. Research shows that precision agriculture can boost crop productivity by 10-30% while decreasing inputs like fertilizers and water (Schmidt *et al.*, 2018).
2. Internet of Things (IoT): IoT devices, such as soil moisture sensors and weather stations, collect real-time data that helps farmers monitor and manage their crops more effectively. By connecting equipment and devices, farmers can make data-driven decisions. A study by Khosrow-Pour (2019) highlights that IoT can improve irrigation efficiency by up to 50%.
3. Drones: Drones are increasingly used in agriculture for tasks such as crop monitoring, soil analysis, and aerial spraying. They provide high-resolution images and data that help farmers assess crop health and identify issues early. According to a report by Dandois and Ellis (2010), drones can significantly reduce the time required for crop surveillance, enabling timely interventions. Drones that employ remote sensing technology can help in gathering data about crop health and land use.
4. Big Data Analytics: Big data analytics allows farmers to process vast amounts of information from various sources, including weather patterns, market trends, and soil health. By analyzing this data, farmers can forecast yields and optimize resource allocation. A study by Zhang *et al.* (2017) found that integrating big data into farming practices can lead to a 20% increase in productivity.
5. Blockchain: Blockchain technology offers secure and transparent supply chain management, enhancing traceability in agricultural products. This technology can help reduce fraud and improve food safety. According to a study by Kamble *et al.* (2019), blockchain can increase consumer trust and enhance the overall efficiency of agricultural supply chains. Discussed innovations not only enhance the productivity of agricultural activities

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but also promote sustainable practices which in turn will contribute to the sustainable development of the sector.

6. Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM): ERP in digital agriculture refers to an integrated software platform that manages and coordinates all key farm or agribusiness processes, such as production planning, input procurement, inventory control, financial accounting, sales, logistics, and human resources, within a unified digital system (Habeeb *et al.*, 2025). CRM in digital agriculture refers to an integrated system designed to manage interactions between agricultural enterprises (such as farms, cooperatives, or agribusinesses) and their customers, suppliers, and partners (Binoy *et al.*, 2023).

1.3. *Challenges and Barriers on The Path to Digital Agriculture*

Digital agriculture holds great potential, but several challenges hinder its widespread adoption. First and foremost, the challenge is technological access and literacy. Many rural areas lack the necessary infrastructure, such as high-speed internet and electricity, to support digital tools, which raises the issue of technological accessibility. Another manifestation of this challenge is the high cost of technology: the cost of purchasing and implementing digital technologies can be prohibitively high for smallholder farmers (Choruma *et al.*, 2024). Another challenge is the lack of digital literacy, as, many farmers don't have the necessary skills to utilize digital tools effectively, leading to underutilization of available technologies (Cheng *et al.*, 2024).

As in the case of any type of innovation digital technologies face resistance stemming from skepticism toward new technologies. Extensive farming practices may lead to resistance against adopting new digital methods, especially if the farmers are old and are used to old-fashioned practices (Klerkx *et al.*, 2019). So behavioral factors must be addressed in policymaking for the successful transition into digital agriculture. Behavioral aspects of digital penetration in agriculture also touch on the issue of data privacy and security concerns from farmers. Farmers may be hesitant to share data due to concerns over privacy and the potential misuse of their information (especially if it includes personal data, income level, etc.) (Pino *et al.*, 2020).

A huge challenge on the path of digital penetration in agriculture is the limited access of farmers to financial resources. Farmers, especially smallholders, often lack access to credit and financial resources necessary for adopting digital technologies (Albrecht *et al.*, 2020).

There is also the problem of difficulties in integrating new technologies with existing, extensive production systems, which can lead to inefficiencies and increased costs (van der Wal *et al.*, 2021).

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1.4. *Case Studies*

Several case studies and evidence-based reports highlight the success stories of digital agriculture. In the US John Deere's adoption of precision agriculture technologies significantly improved productivity in corn and soybean production. Farmers using their technology reported an average yield increase of 10-15% (Wolf & Dyer, 2018). Another example is FarmLogs: this platform helps farmers in the U.S. manage their operations by providing data-driven insights on crop health and soil conditions[1]. A similar platform is employed in Kenya called M-pesa. This mobile platform revolutionized access to financial services for farmers, enabling them to receive payments and access credit (Aker & Mbiti, 2010). Another example is "The Kisan Suvidha" app (developed in India), which provides farmers with real-time information on weather, market prices, and agricultural best practices, resulting in increased income for over 1 million farmers (Kumar & Singh, 2020). In Denmark, the practices of smart farming are rapidly developing. Farmers implemented IoT devices in greenhouse management, leading to a 20% reduction in water usage while maintaining crop yields (van der Wal *et al.*, 2021).

In pest and disease control practices digital technologies provide huge assistance. For example, in Brazil farmers utilized drone technology for monitoring large soybean fields, leading to early detection of pests and diseases. This resulted in an estimated 15% increase in yield (Silva & Costa, 2022). Or in China AI-driven systems have been developed for pest identification and management. This technology has reduced pesticide usage by 30% while maintaining crop productivity (Li & Zhao, 2021).

Digital agriculture represents a transformative approach to farming, leveraging technology to enhance productivity, sustainability, and economic viability. As the agricultural sector continues to evolve, understanding the definition and implications of digital agriculture becomes crucial for stakeholders at all levels. The challenges hindering digital penetration in agriculture are multifaceted, ranging from technological and economic barriers to cultural and regulatory issues. Addressing these challenges requires a coordinated effort among stakeholders, including policymakers, technology providers, and farmers. By tackling these issues, the agricultural sector can unlock the full potential of digital transformation.

While there are challenges to overcome, the potential benefits for productivity, sustainability, and economic growth are substantial. The

1. FarmLogs (2022). Farm Management Software. Retrieved from https://www.farmlogs.com.

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journey to digital agriculture is multifaceted, involving education, technology adoption, data management, and collaboration among various stakeholders. By following these steps and leveraging the provided references, farmers and agricultural professionals can navigate this transformative path effectively.

2. Materials and methods

In the scope of the research, the state of agriculture digitalization in Armenia was assessed. The studying of the level of digitalization, regardless of the field, the purpose of the research, and the scope of inclusion, has specific difficulties. The problem lies in the fact that in RA, in terms of official statistics, there are no statistical publications that will specifically address or provide data about the state of the digital economy and digitalization in general in various spheres of life, which means the availability of official statistical data on the state of digitalization of rural areas is out of the question. Taking into account the research objectives and absence of official statistical data on agriculture digitalization, this article adopted a methodology framework, which was utilized in a similar study by Arion *et al.* (2024) "Determining Digitalization Issues (ICT Adoption, Digital Literacy, and the Digital Divide) in Rural Areas by Using Sample Surveys: The Case of Armenia".

The methodological basis for collecting the primary information about the state of digital agriculture in RA was the method of sample survey. The strata of the survey were the Armenian farms operating in all 10 regions of Armenia. A stratified sampling approach was applied, under which the target survey population (comprising farms) was partitioned into homogeneous strata, and respondents were then selected from each stratum through random sampling to ensure representativeness and reduce sampling bias (Arion *et al.*, 2024).

To determine the sample size the number of all kinds of organizations operating in agriculture must be considered. According to the RA Statistical Committee, the number of economic units engaged in agricultural production (farms) was 360 611[2], which would be the size of the main population of the surveys. To calculate the required representative sample size with a 95% confidence level and 5% margin of error, the following formula was used, developed by Arkin H. and Colton R.:

2. The data was obtained from official statistics of The RA Statistical Committee, source: https://armstat.am/file/doc/99501108.pdf, page 3, last accessed 11.11.2024.

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$$Sample\ size = \frac{\frac{(z^2 p(1-p)}{e^2}}{1 + \frac{(z^2 p(1-p)}{e^2 N}}$$, where:

N - population size,
p - expected rate of occurrence (50%),
e - margin of error (percentage as a decimal) (0.05),
z - this is a value that indicates how much deviation occurs from the mean value. At the confidence level of 95% z = 1.96.

The required sample size for the research was at least 384 units, that is, at least 384 households from rural areas of the RA must participate in the survey to provide a representative sample with a 95% confidence level and 5% margin of error. Considering the obtained number 400 surveys were conducted among Armenian farms in the first half of 2024. All the farms had an equal opportunity to be selected and included in the sample, and the selection of farms was carried out using a random address generator.

To ensure the highest accuracy of the survey results, prevent the inclusion of incomplete questionnaires, and minimize potential response bias, the data collection process was conducted exclusively through structured face-to-face interviews.

Even though low cost-effective and time-consuming compared to online or telephone surveys, this way provided reliable, complete data and the response bias was minimized (all the questionnaires were completed, there was no missing data, and the respondents fully understood the meaning of the questions, so the results were as reliable as possible). The questionnaires consisted of 13 questions, which explore the basic information about farms specifics (average incomes from agriculture activities, specialization, size, etc.) as well as questions specifically related to agriculture digitalization: the use of digital technologies, their accessibility, the attitude towards digitalization, the internet use directions, etc. The results of the survey allowed for forming a comprehensive knowledge about the state of digital agriculture in RA. In the questionaries, the list of digital technologies that are implemented in agriculture was included (see Table 1).

To strengthen the quantitative analysis of the study and identify the key determinants of digital technology adoption at the farm level, a Tobit regression model was employed. The use of the Tobit model is justified by the nature of the dependent variable, which is censored, taking the value 1 when the farm uses at least one digital technology and 0 otherwise (Asatryan *et al.*, 2024). Ordinary Least Squares (OLS) would be inappropriate due to the limited range of the dependent variable, whereas the Tobit specification

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Table 1 - The list of digital technologies implemented in agriculture

1	Digital devices (drones, robots, etc.)
2	Automated systems (irrigation systems, "smart farms", etc.)
3	Sensor devices (hygrometers, soil analysis devices, etc.)
4	Weather forecasting devices, programs, applications, etc.
5	3D printing, modeling
6	Internet of things
7	Cloud computing
8	Big Data
9	Artificial Intelligence (AI)
10	Enterprise Resource Planning (ERP)
11	Customer Relationship Management (CRM)

accounts for censoring at the lower bound and provides consistent parameter estimates. The mathematical expression of the Tobit model is as follows:

$$Y_j = \alpha + X_j \beta + \varepsilon_j, j = 1, 2\ldots, N$$

Where Y_j is the Digital adoption dummy (1 = farm uses at least one digital technology from Table 1; 0 = otherwise).

α is the coefficient of intercept.

X_j is a matrix of explanatory, independent variables. Based on theoretical considerations and data availability, the following explanatory variables were incorporated:

- Farm size (ha) – continuous,
- Farmer age (years) – continuous,
- Education level – categorical (primary / secondary / higher),
- Farm income (AMD) – continuous,
- Production orientation – dummy (1 = animal husbandry; 0 = horticulture),
- Production model – dummy (1 = intensive; 0 = extensive).

These variables capture the structural, socioeconomic, and organizational characteristics of farms that the literature identifies as essential for explaining digital adoption behavior.

ε_j is the stochastic error.

The model was estimated using maximum likelihood estimation. Marginal effects were computed to interpret the influence of each variable on the probability of adopting digital technologies. This approach complements the descriptive findings and provides robust statistical evidence on the factors shaping the digital transition of Armenian farms.

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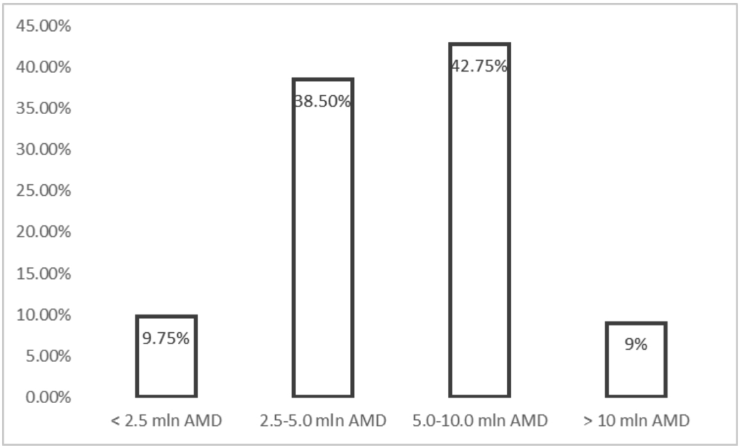
3. Results and discussion

- The descriptive statistics of the surveyed farms are presented below. Of the respondent farms, 55% are specialized only in horticulture, 45% are specialized in animal husbandry, and 18% are specialized in both horticulture and animal husbandry. It must be noted that these two main branches of agriculture have specific requirements for digital penetrations and their cases must be studied separately, Studies show that the prerequisites for digital adoption are different for horticulture and animal husbandry and are strongly conditioned by their production characteristics.
- Since the implementation of digital technologies in agriculture is usually coupled with the transformation of the production model (extensive, intensive, etc.) during the survey the farms were sorted according to those criteria, and results show that the vast majority of farms lead the extensive farming (specifically 83.75%), and only 16.25% use intensive. It must be noted that those with the intensive model have an average farm size of 13.4 ha (in horticulture-specialized farms), and the average farm size for the extensive model was only 2.5 ha, which provides food for thought for further discussions.

Since digital penetration is undoubtedly related to the financial potential of farms, during the surveys the farm's agriculture average income was taken into consideration. The results are presented in Chart 1.

Chart 1 - The composition of surveyed farms according to the income level



The majority of farms fall into the group of 5.0-10.0 million Armenian drams (AMD) income, with the mean value of income of all surveyed farms

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being 5.4 million AMD, for comparison the average wage level in RA is 230*12 = 2760 thousand AMD yearly. Farm income is a crucial determinant on the path to digitalization because it is the main source of funding for digital penetration in agriculture. The income and digital agriculture relationship is more in-depth discussed in the later part of the paper.

One of the cornerstone pieces of data obtained through the surveys is the assessment of the state of digital technology use in RA farms. The list of the technologies is presented in Table 1 and Charts 2 and 3 represent the usage of those technologies.

Chart 2 - The usage of digital technologies in RA farms (part 1)

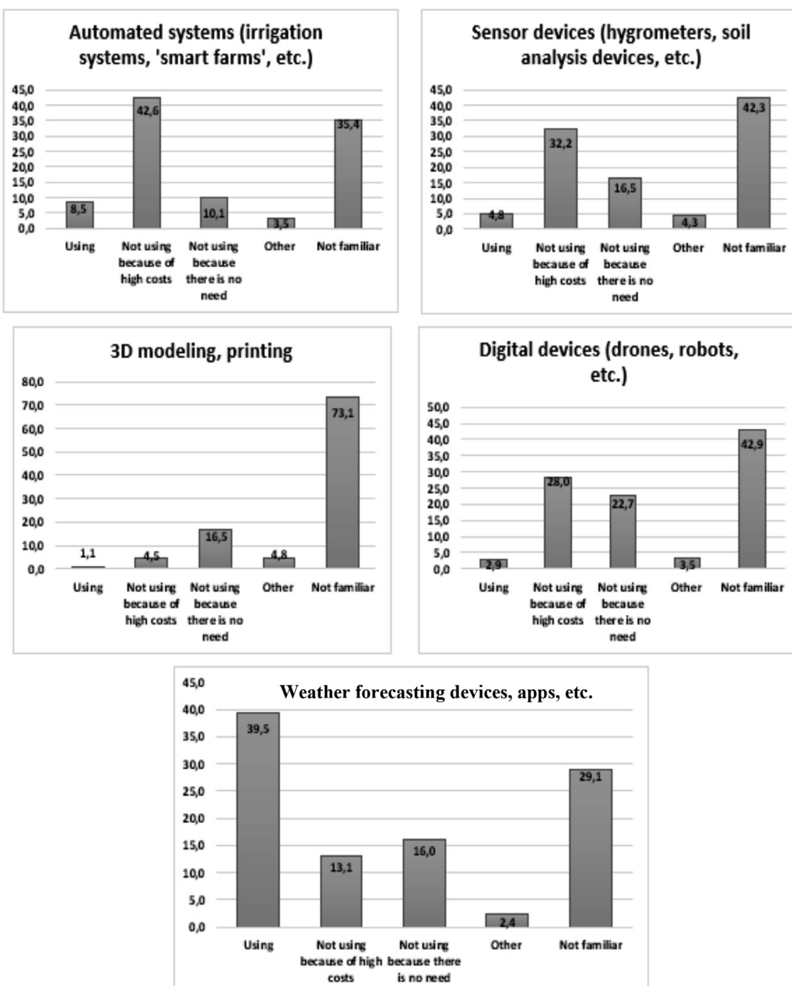

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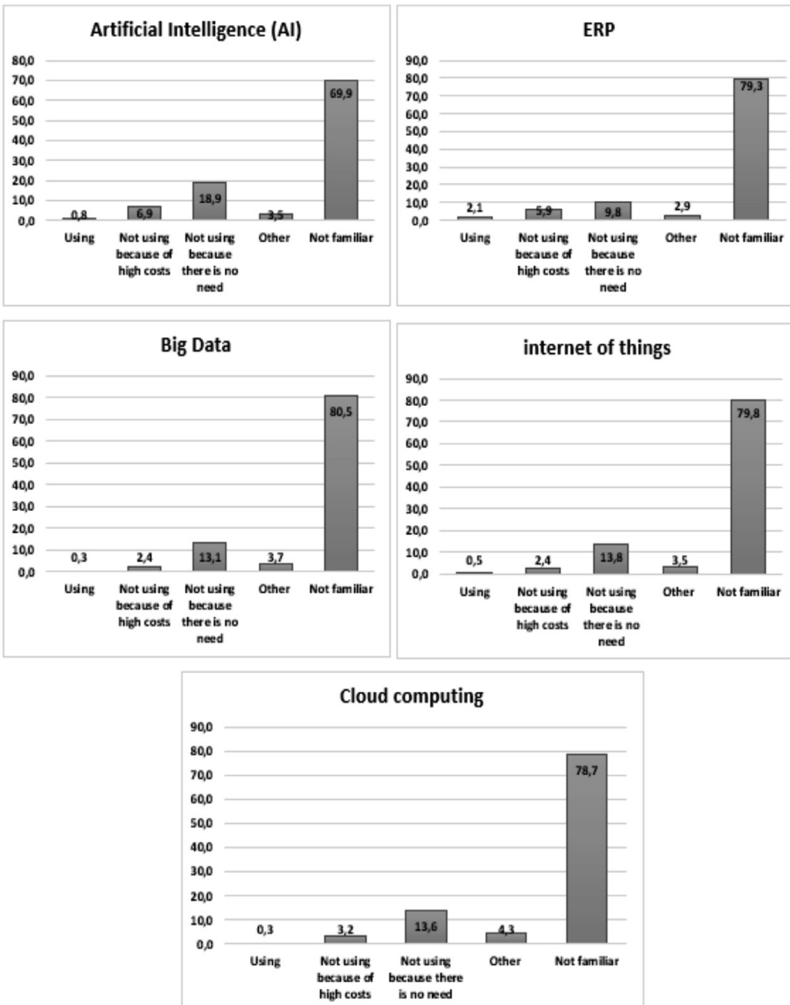
Chart 3 - The usage of digital technologies in RA farms (part 2)



Only 4.8% of surveyed farmers use digital devices such as drones, robots, etc., indicating low adoption. The main barriers include high costs (32.2%) and perceived lack of necessity (16.5%). Notably, 42.3% of farmers are unfamiliar with these devices, suggesting a significant knowledge gap. This lack of familiarity and high-cost perception highlights the need for awareness-raising and possibly financial support to encourage the adoption of digital technologies in agriculture. With automated systems, only 8.5% of respondents use these systems, while a significant portion (42.6%) do not

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use them due to high costs. Additionally, 35.4% are unfamiliar with these technologies, indicating a substantial knowledge gap. About 10.1% of farmers do not perceive a need for these systems. The chart suggests that the main obstacles to adopting automated systems are financial constraints and limited awareness, which could be targeted through education and financial support initiatives. There is low engagement and familiarity with 3D modeling and printing among farms, with lack of awareness being the primary reason for non-use. The majority of surveyed farmers (73.1%) are "Not familiar" with 3D modeling and printing. A smaller portion (16.5%) indicated they are "Not using because there is no need." Only 1.1% are currently "Using" this technology. The farms reporting the use of 3D modeling and printing are those engaged not only in primary production but also in processing and beverage manufacturing. In these cases, 3D modeling is primarily applied within the processing stage (such as in packaging design or equipment optimization) although respondents appear to have generalized its use to the entire scope of farm activities.

Regarding the weather forecasting tools, including devices, programs, and applications: a significant portion (around 40%) of respondents are actively "Using" these tools. However, a notable group (about 25%) is "Not familiar" with them. Some respondents are "Not using because of high costs" (around 10%) or "Not using because there is no need" (about 15%). A small percentage chose "Other" reasons.

A large portion of surveyed farms (42.9%) is "Not familiar" with digital devices. Of those who are familiar, many are "Not using because of high costs" (28.0%) or "Not using because there is no need" (22.7%). Only a small fraction (2.9%) is currently "Using" such devices. So, there is limited usage and high unfamiliarity with digital devices like drones and robots, with cost and lack of need being major barriers for those who are aware of them.

A significant majority of respondents (around 80%) indicated that they are not familiar with Big Data, showing a potential gap in awareness or understanding. A smaller portion (around 10-15%) stated that they are not using Big Data as they don't see a need for it, which may indicate that they either don't see its relevance or lack use cases applicable to their needs. Similarly, a large percentage (approximately 70%) of respondents are not familiar with AI, suggesting that awareness and knowledge of AI might also be low among the participants. Around 15-20% indicated they are not using AI due to a lack of need, hinting that AI applications may not align with their current objectives or industries. Both charts indicate low usage and high unfamiliarity with these technologies, primarily due to a lack of knowledge and perceived necessity. Cost is a smaller but notable barrier. These findings could suggest a need for educational initiatives to increase awareness and demonstrate the potential benefits of Big Data and AI in various fields.

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The majority of respondents (close to 80%) are unfamiliar with ERP and CRM systems, indicating a low awareness of these tools, which suggests an opportunity for increasing education and potentially lowering barriers, such as cost, to encourage usage. The chart also highlights that both cloud computing and IoT have low usage rates among the respondents, with a high percentage of respondents not familiar with these technologies, especially Cloud Computing.

A very important aspect of the path to digital agriculture is the incorporation of the Internet in the agricultural production value chain. Besides production processes, supply and sales must rely on the use of the Internet too. To assess the situation the direction of Internet use for agricultural purposes was revealed, the results of which are summed in Table 2.

Table 2 - The Internet's use for agricultural purpose

Internet's use	**Farms (%)**
To obtain information on land cultivation or livestock management	52.3
For extension services	39.5
To obtain/purchase production means (equipment, machinery, pesticides, fertilizer, etc.)	40.1
To sell their products	30.0
Other	0.8

Results show that internet usage by Armenian farmers for different purposes averages 50%. So nearly half of surveyed farms do not use the Internet for agricultural purposes. Farmers mainly use the internet and its tools for gaining information on land cultivation or livestock management. Yet it must be noted that the bulk of digital technologies simply require the internet to operate. Various apps and platforms that are employed for extension services, pest and disease control, and trade of agricultural goods, just need the use of the internet to be functioned. Studies by Arion *et al.*, (2024) and Harutyunyan *et al.* (2024) show that Internet availability and accessibility in rural areas of Armenia are high, so average and low usage of the Internet for agricultural purposes is not conditioned by the issues of Internet availability in rural, remote areas (Granado-Díaz *et al.*, 2024).

One of the determinants of digital adoption and penetration in agriculture is the behavioral aspect (Granado-Díaz *et al.*, 2024), which encompasses the farmers' attitudes toward digital technologies. The survey results of the attitude of farmers towards digital technologies are presented in Chart 4.

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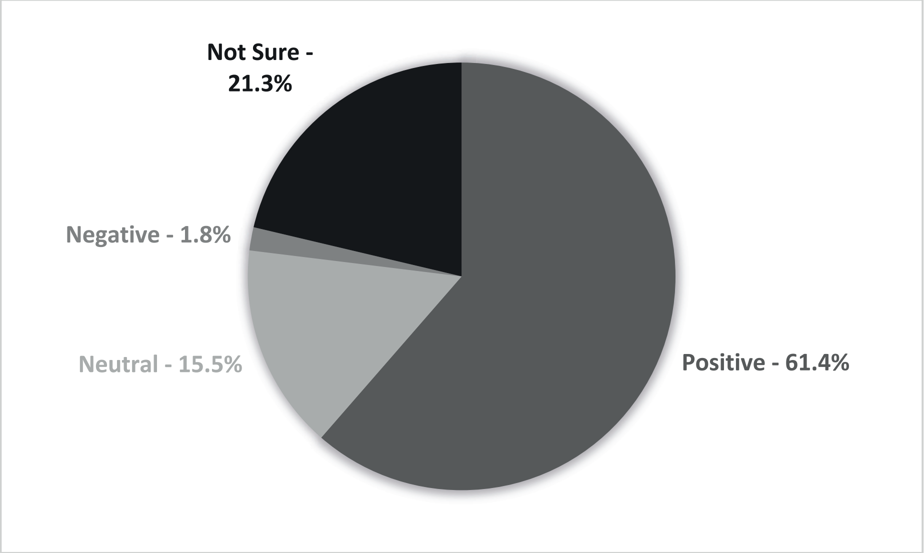
Chart 4 - Farmers' perception of digital technologies' impact on their activities



Survey results indicate that a good portion of Armenian farmers has a positive attitude toward digital technologies, however, the decree of scepticism is rather high. Nearly 40% of the surveyed farmers either found digital technologies' impact neutral or negative or were not even sure about the possible consequences of digital adoption, This raises the question of awareness of farmers, and the issue was apparent regarding the analysis of technologies use. Behavioral analyses again raise the issue of lack of awareness, support, and guidance. These were the main findings of farm surveys.

The Tobit regression results provide robust empirical evidence on the factors shaping digital adoption among Armenian farms. All explanatory variables included in the model are statistically significant, confirming that digital adoption is influenced simultaneously by structural, socioeconomic, and organizational characteristics of farms (Table 3).

Among all determinants, farm size exhibits the largest and most influential coefficient, underscoring its decisive role in the digital transition. Larger farms demonstrate a substantially higher propensity to adopt digital technologies, consistent with the economies of scale argument widely supported in the literature (McBride & Key, 2018; Fountas *et al.*, 2020). This result also aligns with the descriptive statistics, which showed that intensive farms with larger landholdings display greater digital engagement.

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Table 3 - The results of Tobit regression

Variables	Coefficient	Std. Error	z-Statistic	p-value
Farm size (ha)	0.188969	0.036534	4.091881	***
Farmer age (years)	–0.07169	0.003967	–3.96878	**
Education level (1 = higher)	0.070192	0.039827	2.013722	**
Farm income (AMD)	0.089263	0.045698	2.96354	**
Production orientation (1 = livestock)	0.06180	0.004563	3.15476	**
Production model (1 = intensive)	0.12365	0.006978	4.23659	**
Constant	0.423885	0	5.143894	***

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Farmer age shows a negative association with digital adoption, indicating that younger farmers are more inclined toward technological integration. This pattern reflects generational differences in familiarity, openness, and perceived ease of use of digital tools.

Education level positively affects adoption, suggesting that more educated farmers are better equipped to understand, evaluate, and implement digital solutions. This finding reinforces the importance of human capital and digital literacy in driving digital transformation.

Farm income also demonstrates a positive and significant effect, implying that financial capacity remains a key enabling factor for digitalization. Higher-income farms have greater ability to invest in digital tools, absorb risks, and cover operational costs associated with technology use.

Production orientation is significant as well: animal husbandry farms exhibit a higher likelihood of adopting digital tools compared to horticultural farms. This difference is consistent with the technological specificity and monitoring needs typically associated with animal husbandry.

The production model (intensive vs. extensive) has a strong positive effect, indicating that farms operating under intensive models are significantly more likely to adopt digital technologies. This reflects both structural readiness and the higher expected returns from digital investments.

Overall, the econometric results highlight that farm size is the most powerful single predictor of digital adoption, while age, education, income, production orientation, and production model all contribute meaningfully to shaping the technological trajectory of Armenian farms. These findings reinforce the conclusion that digital agriculture in Armenia is constrained

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primarily by structural factors, especially small farm sizes, and that targeted policies addressing scale, education, and financial access are essential to accelerate digital transformation. By summing up the previous literature review results and survey results the main challenges on the path of digital adoption were listed and presented in Table 4.

Table 4 - Main challenges on the digital adoption in agriculture

Challenges most mentioned and discussed in scientific literature	**Challenges that were mentioned by Armenian farmers (according to their intensity)**
Technological access	The small size of farms (81.6% of respondents)
Digital literacy	Lack of financial resources (80.2% of respondents)
High costs of technology	Skills and literacy issues related to digital technology use (78.3% of respondents)
Skepticism and resistance toward new technologies	Physical unavailability issues or high costs of digital technologies (75.1% of respondents)
Data privacy	Skepticism (25.4% of respondents)
Limited financial resources	Lack of awareness (24.7% of respondents)
Integration issues with extensive farming	Lack of state support and guidance (21.5% of respondents)

In contrast to global trends, where limited technological access and low digital literacy are typically identified as the primary barriers to digital penetration, in Armenia the challenges largely stem from the small size of farms, which underlies many of the obstacles reported by respondents. The land plots in Armenia are very small, as are animal breeding farms (with few animals). These small farms have neither the scale nor the capacity to adapt to various digital technologies. In some cases, not adopting the digital technologies by farms is justified, as it does not provide necessary cost efficiency. The adoption of digital technologies in agriculture is influenced by various determinants that can be broadly categorized into individual, organizational, and contextual factors. Cost-benefit effectiveness is one of those determinants.

Several studies discuss farm size and digital adoption relations. McBride and Key state that larger farms can spread the costs of technology over

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a greater output, making the investment in digital tools more feasible (McBride & Key, 2018). Logically this leads to higher rates of digital adoption among large farms. Larger farms typically have greater access to financial resources, skilled labor, and management expertise, facilitating the acquisition and implementation of digital technologies (Fountas *et al.*, 2020). Larger farms may have a more robust ability to absorb risks associated with technology adoption, such as implementation costs and potential failures. This willingness to take risks can lead to faster adoption of digital solutions (Deichmann *et al.*, 2020). Larger farms often have more diverse production systems, making it easier to justify investments in tailored digital technologies that optimize various aspects of their operations (Ward & Sweeney, 2021). Larger farms are more likely to engage in networks that facilitate knowledge sharing and access to innovation, enhancing their capacity to adopt digital technologies (Klerkx *et al.*, 2019).

The findings of foreign authors complement the results obtained in this study. In summary, it can be stated that farm size does matter on the path of agricultural digitalization, as larger farms are generally more equipped to adopt digital technologies due to their ability to leverage economies of scale, access resources, manage risks, and navigate operational complexities. So, on the path of agricultural digitalization in Armenia, the issue of farm size must be addressed during policymaking because it will indirectly promote digital adoption.

By summarizing the main challenges that hinder digital adoption the following conditions can be singled out that promote digitalization in agriculture:

- Infrastructure Availability (access to reliable internet, mobile networks, and necessary hardware, and devices).
- Digital Literacy of Farmers.
- Perceived Usefulness (farmers are more likely to adopt technologies they perceive as beneficial) and easy to use.
- Supportive Regulatory Environment from State.
- Availability of Financial Resources (access to loans and financial assistance can promote the ability of farmers to invest in digital technologies).

Since digital penetration in agriculture is provided through farms operating at the macro level of the economy, then understanding and discussing various farm-specific variables that can affect farmers' decisions to integrate technology into their practices becomes essential. Farm size is already discussed, so let's just mention it as a prominent farm-level variable for digital adoption. Next is farm specialization, particularly crop type, or animal type depending on which agriculture subsector it is. Different crops may require different technological applications. For example, high-value crops often see higher rates of digital adoption due to greater potential returns on

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investment (Ward & Sweeney, 2021; Manucharyan, 2025). Related to farm specialization the geographical location of the farm is an important variable too. Location impacts access to technology, infrastructure, and knowledge networks (Khachatryan *et al.*, 2025). Regions with better infrastructure tend to see higher adoption rates (Reddy *et al.*, 2021). Availability of financial resources is another variable, as access to capital and credit significantly influences the ability of farmers to invest in digital technologies. Farmers with better financial resources are more likely to adopt new technologies (Albrecht *et al.*, 2020). In line with the necessary infrastructure and financial resources, the availability of skilled labor also affects digital penetration, as farms with a workforce that has higher digital literacy are more likely to integrate technology effectively (Klerkx & Rose, 2020). However, money and labor are not the only factors that must be accessible to farmers: Access to Extension Services is important, because support from agricultural extension services can facilitate technology adoption. Knowledge transfer through extension services enhances farmers' confidence in using digital tools (Lobo *et al.*, 2020). Other inter-farm variables are the production goals and management practices. Farmers' management styles and openness to innovation play a critical role. Those who prioritize modern management practices are more likely to adopt digital tools (Klerkx *et al.*, 2019). Farmers' objectives regarding productivity, sustainability, and efficiency can drive adoption. Farms focused on high productivity often invest more in digital solutions (Bock, 2019).

Understanding these farm variables is crucial for developing targeted strategies to enhance digital adoption in agriculture. By addressing the specific needs and contexts of different farms, stakeholders can facilitate the transition to more technologically advanced agricultural practices.

Conclusion

The digitalization of Armenian agriculture remains constrained by a combination of structural, economic, and behavioral factors, the most prominent of which is the small scale of farms. While descriptive survey results already suggested a clear divide between extensive and intensive farming models, the Tobit regression analysis provides strong empirical confirmation of the determinants shaping digital adoption. All variables included in the model were statistically significant, with farm size emerging as the most influential predictor of digital adoption. This reinforces the international consensus that larger farms, benefiting from economies of scale, stronger financial capacity, and a higher ability to absorb technological risks, are substantially more likely to adopt digital tools. In contrast, the

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predominance of small, extensive farms in Armenia severely limits the feasibility and perceived usefulness of digital solutions. Other determinants (including age, education, income, production orientation, and production model) also play essential roles in shaping adoption. Younger and more educated farmers are more open to integrating digital tools, while farms with higher income and intensive production structures show greater readiness for digital transformation. These findings confirm that digital adoption is a multidimensional process shaped simultaneously by human capital, financial capacity, and organizational features of farms. Behavioral and informational factors further compound these structural challenges. Low digital literacy, limited awareness of technological benefits, and skepticism toward digital tools collectively restrict the willingness of farmers to engage with emerging technologies. Despite high availability of internet infrastructure in rural Armenia, its limited use for agricultural purposes reveals a disconnect between infrastructural access and actual digital engagement.

To unlock the full potential of digital agriculture in Armenia, several strategic actions are recommended:

1. Education and Training: Providing farmers with targeted training on digital tools and their benefits is essential for effective adoption.
2. Policy Support: Policymakers should create frameworks to promote digital penetration. Given the current lack of awareness and skepticism, support programs should focus on building awareness and fostering positive attitudes toward digital technologies. Additionally, financial support for farms investing in digital practices is crucial.

In summary, for Armenia's agriculture sector to successfully digitalize, the following are key:

- robust policy support from the government;
- farmer education and increased awareness;
- policies promoting land consolidation.

The role of state support is especially critical in fostering digital agriculture in Armenia. However, as of October 2025, the Armenian Government has not implemented a state support program specifically promoting digital agriculture. Of the 15 support programs administered by the RA Ministry of Economy[3], only a few indirectly address digital adoption. The issue of small farm sizes has been addressed through two currently operating programs (the Pilot Program of Land Reform and the Program for Consolidation of Agricultural Land in Armenia, 2023-2025) which aim to create larger, more viable farming units.

3. The Official website of the RA Ministry of Economy, source: https://mineconomy.am/en/page/1338, last accessed 11.11.2024.

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In conclusion, digitalizing Armenian agriculture requires a nuanced, multifaceted approach that considers both macro-level and farm-specific variables. Policymakers and stakeholders must recognize the diverse needs and capabilities of farms across various agricultural sectors. By doing so, they can create a more inclusive digital landscape that bridges gaps in financial resources, technical knowledge, and access to technology. With targeted support and strategic interventions, Armenia can progressively overcome current barriers, paving the way for a digitally enabled agricultural sector that enhances productivity, sustainability, and resilience.

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Declarations

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no competing interest.

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