

PREDICTION OF THE DEVELOPMENT OF MODERN AGRICULTURE AS A FUNCTION OF ARTIFICIAL INTELLIGENCE AND DIGITALIZATION

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Abstract

The contemporary agricultural sector faces numerous challenges arising from climate change, the growing global demand for food, and the need for sustainable resource management. In such circumstances, digitalization and the application of artificial intelligence have become key instruments for modernizing and enhancing the competitiveness of the agricultural sector. The aim of this study was to examine the impact of the application of artificial intelligence in agriculture and digitalization in agriculture on agricultural development, on the basis of which a theoretical research model was developed. The research was conducted on a sample of 277 respondents, consisting of active and potential agricultural entrepreneurs from the territory of the Republic of Serbia. Data were collected using an anonymous online questionnaire in the form of a Google Form during the period from 1.09.2025. to 31.10.2025. Out of 369 distributed questionnaires, a response rate of approximately 75% was achieved. The research instrument was based on a five-point Likert scale. Data analysis included descriptive statistics of respondents' profiles, reliability analysis of the questionnaire scale Cronbach's α , and correlation and regression analysis of the defined independent predictors and the dependent variable. The results indicate that both the application of artificial intelligence and digitalization in agriculture have a

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statistically significant and positive effect on agricultural development. Digitalization in agriculture proved to be a stronger individual predictor, while the effect of artificial intelligence application was comparatively weaker. Model explains 81.20% of the variance in agricultural development $R^2=0.812036$, whereby the proposed hypothesis was rejected.

Key words: Application of AI in agriculture, digitization in agriculture, development of agriculture.

JEL⁶: Q16, O16, Q55

Introduction

The contemporary business environment, characterized by accelerated digitalization and growing demands for sustainable development, presents organizations with new challenges, as well as significant opportunities for creating long-term value (Vujičić, 2025). The growth of the global population, climate change, limited natural resources, and the need to increase productivity while preserving the environment, represent the major challenges faced by the agricultural sector in the 21st century. According to the Food and Agriculture Organization of the United Nations (FAO, 2017), global food production must significantly increase to meet rising demand, while at the same time reducing negative impacts on ecosystems. Under such conditions, technological innovations become a key factor in the transformation of the agricultural sector, with digitalization and the application of artificial intelligence (AI) occupying a central role. Number of authors (Agrawal, 2016; Zakić et al., 2017; Vujičić et al., 2019; Milanović et al., 2020; Šormaz, 2021; Vujičić et al., 2021; Vemić et al., 2022; Puška, Štilić, 2022; Stojković Hadži et al., 2022; Šćepanović et al., 2023; Krmpot et al., 2024; Cindrić et al., 2024; Krmpot et al., 2025) emphasize the importance of technological progress, innovation, and education in all areas of business activity, particularly in agriculture.

The digital transformation of agriculture involves the integration of information and communication technologies, sensor systems, satellite data, big data analytics, and decision-support systems into everyday production processes. This concept is often associated with the notion of “smart farming” or “precision agriculture,” which refers to the use of technology to optimize inputs and increase production efficiency (Wolfert et al., 2017). Precision agriculture enables detailed monitoring of soil variability, climatic conditions, and crop growth, thereby ensuring more rational use of water, fertilizers, and pesticides (Somashekar et al., 2024).

In today's business environment, AI represents an advanced stage of digital transformation. AI systems based on machine learning and deep learning enable the analysis of large volumes of data collected through sensors, drones, satellite imagery, and IoT devices, with the aim of yield prediction, plant disease identification, optimization of sowing and harvesting time, and improvement of supply chain logistics (Kamilaris, Prenafeta Boldú, 2018). Liakos et al. (2018) emphasize that the application of AI in agriculture significantly contributes to precise production management and the reduction of risks associated with climate variability. Furthermore, digitalization and AI play an important role in enhancing the value of agri-food supply chains. Klerkx et al. (2019) point out that digital platforms enable better connectivity among producers, distributors, processors, and final consumers, thereby reducing transaction costs and increasing market transparency.

Empirical research confirms that the application of digital technologies has a positive effect on farmers' productivity and income. Lei and Yang (2024) argue that digitalization contributes to increased production efficiency and income growth through better resource management and reduced operational costs. Peng et al. (2024) emphasize that the use of digital tools improves decision-making and reduces uncertainty in production processes. Today, AI expands the possibilities of digitalization by enabling the development of predictive models and automated management systems. The integration of AI and IoT technologies (AIoT) represents a key component in the development of smart agricultural systems, where real-time data are used for continuous adjustment of production processes. However, the digital transformation of agriculture faces several obstacles, such as insufficient digital infrastructure in rural areas, limited access to financial resources, and lack of digital competencies among farmers (Klerkx et al., 2019). Dmitrović et al. (2024) note that the main risks associated with the use of new technologies in agriculture in many countries include insufficient knowledge about technology and high implementation costs, while its greatest potential lies in increasing income with reduced human labour engagement. Farmers' willingness to adopt new technologies represents one of the key factors for the successful implementation of innovations.

In line with the above, the subject of this paper is to examine the impact of AI application and digitalization in agriculture on agricultural development. Special attention is given to the analysis of the interrelationships among these factors and their joint role in enhancing productivity, competitiveness, and sustainability in the agricultural sector. Understanding these relationships has significant implications for designing policies that support digital transformation, infrastructure investment, and farmer education.

Application of Artificial Intelligence (AI) in agriculture

Population growth, climate change, land degradation, and limited natural resources, require increased productivity while simultaneously preserving the sustainability of agroecosystems. According to the FAO report (FAO, 2017), the future of food and agriculture depends on the sector's ability to integrate innovative technologies that enable more efficient resource management and the reduction of negative environmental impacts. Digital technologies, particularly the internet, mobile platforms, cloud computing, and AI, are accelerating today's transformation by reshaping production methods, communication, and management processes, as well as the structure of labour demand and required skills (Prlić, 2025).

AI represents one of the key technologies capable to transform the production, management, and distribution of agricultural products. It offers potential solutions across numerous areas of agricultural production, creating new opportunities for modern agriculture, especially precision farming, in the development of integrated farm management systems. Drones, robots, and automated monitoring systems constitute significant components of agricultural innovation. Neina (2019) and Naz et al. (2022) emphasize that AI supports the analysis and management of key environmental variables such as soil pH, or ambient temperature (Ye et al., 2012; Badugu et al., 2024), and precipitation (Lebu et al., 2024; Chen et al., 2024).

The application of AI is particularly important in resource management. Algorithms based on the analysis of temporal data, soil moisture, and meteorological parameters enable precise determination of optimal sowing, fertilization, and harvesting times. Such systems enhance production efficiency and reduce the risks associated with climate variability.

Beyond its direct impact on production processes, AI contributes to improving agri-food value chains. Data-driven digital platforms facilitate better logistics planning, storage optimization, and more efficient product distribution. Klerkx et al. (2019) emphasize that digital agriculture is reshaping institutional and organizational structures within the sector by creating new models of cooperation among producers, markets, and institutions.

In terms of sustainability, the application of AI has significant potential to reduce greenhouse gas (GHGs) emissions and promote more rational use of natural resources. Precise input dosing decreases excessive use of pesticides and mineral fertilizers, while soil health monitoring systems help preserve long-term soil fertility. FAO (2017) highlights that digital innovations represent a key factor in achieving sustainable development goals in agriculture. However, the implementation of AI in agriculture faces certain challenges. Klerkx et al. (2019) point out that successful

digital transformation requires institutional support, education, and the development of competencies among all stakeholders in the agricultural sector. Issues related to data governance, privacy, and ethical aspects of AI application also remain relevant. Despite these challenges, empirical research indicates that the application of AI has a positive impact on agricultural productivity and competitiveness. The integration of AI with IoT technologies (AIoT) enables continuous real-time data collection and analysis, thereby improving decision-making and increasing system resilience to external shocks. Such models contribute to the long-term development of agriculture and the strengthening of rural economies.

The application of AI in agriculture represents a significant step toward modernization and sustainable sectoral development. The combination of advanced analytical tools, digital infrastructure, and professional expertise enables the transformation of traditional production systems into smart and efficient agro-economic models.

Digitalization in agriculture

Digitalization refers to the process through which digital technologies create new opportunities for value creation. In agriculture, digitalization represents one of the most important directions of transformation within the modern agrarian sector. It provides farmers with relevant and timely information and services, facilitating agricultural activities and leading to increased profitability and sustainable operations. Ugochukwu and Phillips (2018) emphasize that digitalization is emerging as a powerful driver of rural income growth, food security, and national economic development by enabling informed decision-making and connecting small-scale producers with profitable markets. In the context of rising global food demand, climate change, limited natural resources, and the need to improve production efficiency, the integration of digital technologies becomes a key factor in the sustainable development of agriculture. Charatsari et al. (2020) and Fielke et al. (2020) define digitalization in agriculture as the use of software, hardware, and data to increase productivity and efficiency, while reducing costs, labour requirements, and environmental impact.

Digital platforms play a significant role in improving the organization and management of agricultural holdings. They provide access to market information, input and product prices, weather forecasts, and advisory services. Klerkx et al. (2019) emphasize that digital agriculture involves not only technological change, but also institutional and organizational transformation, as digital technologies reshape relationships among producers, markets, and public institutions. Digital platforms facilitate producer-consumer connections, reduce transaction costs, and enhance market transparency.

Precision agriculture, as an integral component of digitalization, relies on GPS technology, satellite imagery, and drones for field mapping and crop condition analysis. Based on collected data, it is possible to identify zones with varying water and nutrient requirements, enabling differentiated input application. Kamilaris and Prenafeta Boldú (2018) highlight that digital technologies allow the integration of data from multiple sources and their processing through advanced algorithms, contributing to more precise and informed decision-making.

Digitalization also significantly impacts the sustainability of agricultural production. Precise resource management reduces the excessive use of pesticides and fertilizers, thereby minimizing environmental damage and contributing to biodiversity conservation. From an economic perspective, digitalization enhances the competitiveness of the agricultural sector. Improved data management enables cost reduction, logistics optimization, and minimization of supply chain losses. FAO (2017) notes that digital innovations have the potential to strengthen the resilience of agricultural systems and increase farmers' incomes, particularly in developing countries.

Agricultural development

Agricultural development represents a complex and multidimensional process encompassing economic, technological, social, and environmental aspects of the transformation of the agrarian sector. In contemporary business conditions, agriculture can no longer be viewed solely as a primary food production activity, but rather as a strategic sector for sustainable development and rural stability. According to the OECD (2019), sustainable agricultural development involves simultaneously improving productivity, preserving natural resources, and ensuring the economic sustainability of rural areas. The economic dimension of agricultural development refers to increasing productivity and competitiveness within the sector. The modernization of production systems, the adoption of new technologies, and the improvement of production processes are key factors in enhancing agricultural productivity. Fuglie (2018) emphasizes that long-term growth in agricultural production largely depends on technological progress and innovation, rather than merely increasing input use. Technological innovations enable more efficient utilization of land, labour, and capital, thereby increasing total factor productivity.

In Serbia, agricultural development holds particular importance due to its contribution to gross domestic product and rural employment. Parušić and Cvijanović (2014) emphasize that the competitiveness of Serbian agriculture depends on production modernization, improved market orientation, and strengthened institutional support. The development of rural areas in Serbia requires an integrated approach

that encompasses not only agriculture but also the diversification of economic activities, infrastructure development, and the improvement of quality of life in rural communities.

Sustainable agricultural development implies a balance between economic efficiency and environmental preservation. Climate change represents one of the greatest challenges for modern agriculture, as it affects yields, crop structures, and production stability. The IPCC (2022) stresses that adaptation to climate change requires the introduction of climate-smart practices, improved land management, and the application of innovative technologies. Therefore, agricultural development must be directed toward models that reduce GHGs emission and promote sustainable natural resource management. Consequently, innovation and digital transformation have become key drivers of agricultural development. The application of modern information technologies can contribute to increased efficiency, transparency, and competitiveness of the agricultural sector in Serbia. Digitalization enables more precise production planning, optimization of inputs, and risk reduction.

In addition to technological factors, the institutional framework plays a crucial role in agricultural development. Agricultural policy, subsidies, access to financial resources, and farmer education directly influence the speed and quality of sectoral transformation. In rural and agricultural areas, education may play an even more significant role, as it contributes to production modernization, improved application of agronomic practices, and more efficient resource use (OECD, 2019). According to a study conducted by FAO (2017), there is a clear link between farmers' education levels and their ability to diversify production, adopt innovative technologies, and gain better access to markets. Similarly, farmers with higher levels of education are more likely to use information and communication technologies, and to access financing and subsidies (Nikolić et al., 2025).

Methodology

Starting from the theoretical framework and the established research hypotheses, the research design has been conceived with the aim of conducting a quantitative analysis of the interrelationships between the variables of artificial intelligence application in agriculture, agricultural digitalization, and agricultural development. The following variables have been defined:

Application of AI in agriculture, hereinafter abbreviated (AIA):

- AIA₁ - The application of AI enables more precise management of agricultural production.

- AIA₂ - The use of systems based on AI contributes to increasing yields in agriculture.
- AIA₃ - The application of AI reduces production costs in agriculture.
- AIA₄ - Technologies based on AI enable more effective monitoring of the health status of plants and soil.
- AIA₅ - AI has great potential for improving sustainable agricultural production.

Digitization in agriculture, hereinafter abbreviated (DTA):

- DTA₁ - Digital technologies enable more efficient management of agricultural holdings.
- DTA₂ - The use of digital platforms facilitates access to information important for agricultural production.
- DTA₃ - Digitization contributes to better organization and planning of agricultural activities.
- DTA₄ - The use of digital tools (apps, sensors, software) increases productivity in agriculture.
- DTA₅ - Digital technologies improve communication between farmers, markets and institutions.

Development of agriculture, hereinafter abbreviated (DPA):

- DPA₁ - The introduction of new technologies contributes to the long-term development of agriculture.
- DPA₂ - The modernization of agriculture leads to an increase in productivity and production quality.
- DPA₃ - Technological progress has a positive effect on the sustainable development of agriculture.
- DPA₄ - Modern approaches to production contribute to strengthening the competitiveness of the agricultural sector.
- DPA₅ - The development of agriculture depends on the willingness of farmers to accept new technologies.

Task of the research is to determine: Do (AIA) and (DTA) affect or not (DPA)? Meanwhile, the null hypothesis (H_0) is set as: The application of AI and digitization in agriculture do not have a statistically significant impact on the development of agriculture.

The research was conducted on active and potential agricultural entrepreneurs from the territory of the Republic of Serbia. The research was performed anonymously

online in the form of a Google questionnaire in the period from 1.09.2025. to 31.10.2025. The questionnaire was distributed to 369 email addresses, while 75% was returned as responses in the specified time period. The first part of the research concerned the analysis of the respondent's profile according to: Respondent's gender, Respondent's age, Respondent's education level, and Respondent type.

Then, the reliability analysis of the Cronbach α scale was performed for the statements formed regarding the influence of (AIA) and (DTA) on (DPA).

The questions were structured so that respondents rated the presented statements by expressing their personal opinions using a Likert scale ranging from 1 to 5 (5 - completely agree; 4 - partially agree; 3 - neither agree nor disagree; 2 - disagree; 1 - completely disagree).

In the sample, male respondents predominate, accounting for 66.79%, while female respondents represent 33.21% of the total sample (Table 1. and Figure 1.). This disproportion indicates a pronounced gender imbalance within the observed sector, consistent with the traditional structure of agricultural activity. The research findings therefore primarily reflect the attitudes of the male population to a greater extent.

Table 1. Respondent's gender

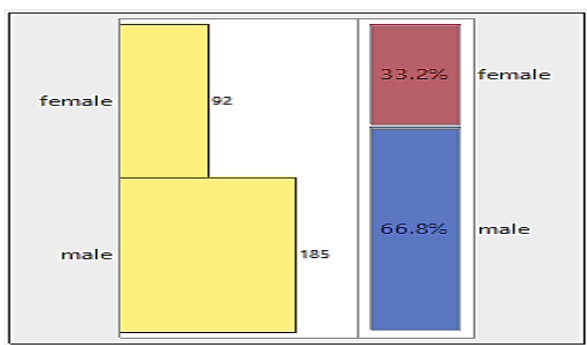
Level	Count	Prob
Male	185	0.66787
Female	92	0.33213
Total	277	1.00000

Source: According to research data.

The results may reflect a technically pragmatic, but less inclusive perspective on the digital transformation of agriculture.

A more detailed examination of the respondents' age structure (Table 2. and Figure 2.) shows that the most represented individual categories are those aged 26-35 (23.83%) and 36-45 years (23.11%), while a notable proportion of respondents aged over 65 is also presented (20.58%). The distribution is relatively balanced, albeit with a slight emphasis on younger respondents. The presence of nearly 28% of respondents older than 55 is particularly significant, as it indicates the intergenerational character of the sample.

Figure 1. Respondent’s gender



Source: According to research data.

Table 2. Respondent’s age

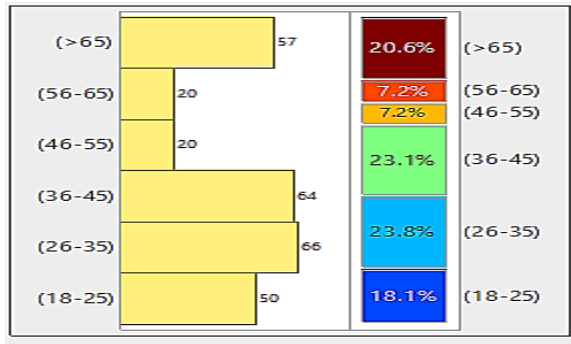
Level	Count	Prob
(18-25)	50	0.18051
(26-35)	66	0.23827
(36-45)	64	0.23105
(46-55)	20	0.07220
(56-65)	20	0.07220
(>65)	57	0.20578
Total	277	1.00000

Source: According to research data.

Younger respondents, accounting for approximately 42%, represent the primary adopters of artificial intelligence, digital platforms, and automation technologies. Older respondents, comprising around 28% of those over 55 years of age, may act as carriers of experience and traditional knowledge. However, they potentially exhibit a higher level of resistance to technological change. Within this sample, the development of modern agriculture depends on the interaction between the innovativeness of younger respondents and the experience of older ones. In this context, the digital transformation process may be hindered in the absence of effective intergenerational integration.

The respondents’ educational level (Table 3. and Figure 3.) is distributed as follows: secondary and primary education accounts for 54.51%, while higher and tertiary education represents 45.49% of the sample. The difference is relatively small, at approximately 9%, indicating a satisfactory representation of formally more educated respondents. The sample is not predominantly “low-educated”, but rather demonstrates a solid intellectual capacity for understanding contemporary technologies.

Figure 2. Respondent’s age



Source: According to research data.

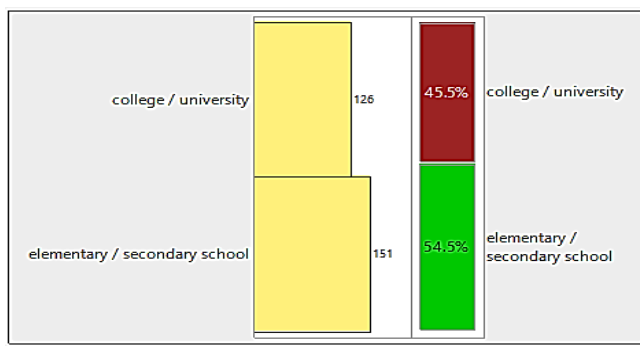
Table 3. Respondent’s education level

Level	Count	Prob
Elementary / secondary school	151	0.54513
College / university	126	0.45487
Total	277	1.00000

Source: According to research data.

The relatively high share of highly educated respondents (45.49%) indicates a substantial capacity for understanding complex AI systems and a greater likelihood of adopting digital tools. Education acts as a positive moderator in the relationship between digitalization and agricultural development.

Figure 3. Respondent’s education level



Source: According to research data.

The respondents' type (entrepreneurial status), (Table 4. and Figure 4.) is distributed as follows: active agricultural entrepreneurs account for 69.68%, while potential agricultural entrepreneurs represent 30.32% of the sample. These respondents make actual investment decisions and directly influence the implementation of AI and digital technologies.

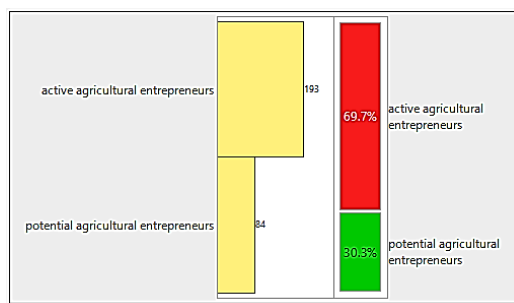
Table 4. Respondent type

Level	Count	Prob
Potential agricultural entrepreneurs	84	0.3032
Active agricultural entrepreneurs	193	0.6968
Total	277	1.00000

Source: According to research data.

The sample demonstrates a high implementation potential, indicating that the findings are not merely theoretical but also have practical relevance.

Figure 4. Respondent type

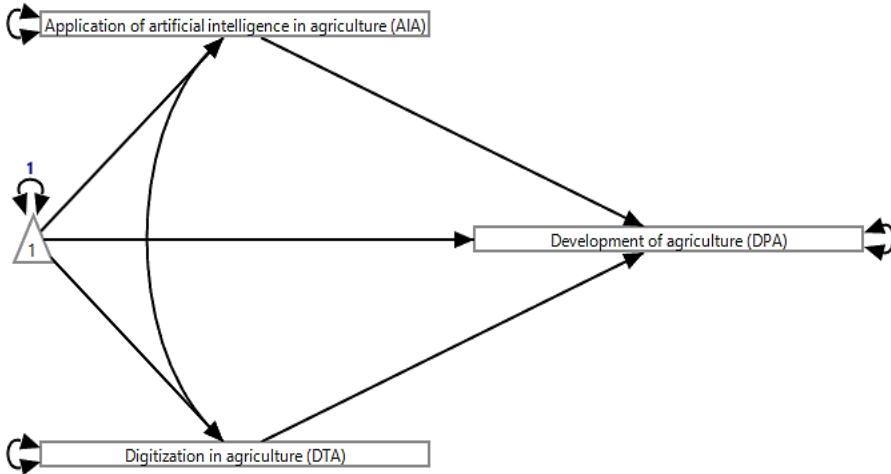


Source: According to research data.

The respondent profile comprises a sample of 277 individuals who demonstrate a solid capacity for the adoption and implementation of artificial intelligence and digitalization in agriculture, albeit with certain limitations. The positive characteristics of the sample include a high proportion of active entrepreneurs and a substantial level of education, both of which support the development of modern agriculture based on AI technologies. The limiting factors, such as age heterogeneity and gender imbalance, may slow down or narrow the direction of the digital transformation process. The strategic implication of the sample is that future development depends on the ability to connect younger, technologically oriented actors with older, experienced producers, while simultaneously enhancing inclusiveness and sector-wide education. There is a realistic basis for predicting accelerated development of modern agriculture. However, this is contingent upon systematic support for digital education and knowledge transfer within the observed sample framework.

In next figure (Figure 5.) is shown the theoretical research model, based on which the hypotheses were formulated. It consists of two independent variables (Application of AI in agriculture and Digitization in agriculture), the dependent variable (Development of agriculture) and the means/intercepts (no. 1), view from JMP Pro 18 software.

Figure 5. Theoretical research model



Source: According to authors point of view

Table 5. presents a reliability analysis of the scale using Cronbach's alpha through the "alpha if item deleted" procedure, which assesses how the removal of individual items would affect the internal consistency of the construct measuring the application of AI in agriculture.

The results indicate the following dimensions: The most important predictor is yield enhancement through AI systems (AIA_2); The technological foundation of AI application is reflected in precision management and monitoring (AIA_1 and AIA_4); The economic factor is represented by the reduction of production costs (AIA_3); The strategic dimension is captured through the improvement of agricultural sustainability (AIA_5).

Table 5. clearly shows that the application of AI in agriculture is primarily based on yield enhancement and production optimization, followed by improvements in precision management and monitoring, while cost reduction and sustainability represent important but secondary determinants of AI adoption in modern agriculture.

Table 5. Cronbach α Application of AI in agriculture

Claim label	Claim description	Cronbach α (if omitted)	Contribution interpretation	Predictive significance for the application of AI in agriculture
AIA ₁	The application of AI enables more precise management of agricultural production	0.8127	High consistency; strongly aligned with other variables	Precision management represents a fundamental aspect of AI application, enabling optimization of inputs and decision-making processes
AIA ₂	The use of systems based on AI contributes to increasing yields in agriculture	0.8437	Highest value; central variable within the construct	Yield improvement is the primary driver of AI adoption and a key predictor of its application in agriculture
AIA ₃	The application of AI reduces production costs in agriculture	0.7778	Lowest but acceptable value; slightly weaker association	Cost reduction is recognized but perceived as less immediate, indicating potential barriers related to investment and implementation
AIA ₄	Technologies based on AI enable more effective monitoring of the health status of plants and soil	0.78	Stable contribution; operationally important dimension	AI-based monitoring enhances control over biological processes and reduces production risks
AIA ₅	AI has great potential for improving sustainable agricultural production	0.7842	Good integration within the construct; not dominant	Sustainability is an important long-term outcome of AI application, though secondary to productivity gains

Source: According to research data.

Table 6. presents a reliability analysis of the scale using Cronbach's alpha through the "alpha if item deleted" procedure, which evaluates how the removal of individual items would affect the internal consistency of the construct measuring digitization in agriculture.

The results indicate the following dimensions: The most important predictor is productivity enhancement through digital tools (DTA₄); The technological foundation of digitization is reflected in efficient management and planning (DTA₁ and DTA₃); The informational dimension is represented by access to relevant data and information (DTA₂); The integration factor is captured through the improvement of communication among actors in the agricultural system (DTA₅).

Table 6. clearly shows that digitization in agriculture is primarily based on increased productivity and production efficiency, followed by improvements in management and organizational processes, while access to information and enhanced communication represent key infrastructural and integrative elements of the digital transformation of agriculture.

Table 6. Cronbach α Digitization in agriculture

Claim label	Claim description	Cronbach α (if omitted)	Contribution interpretation	Predictive significance for digitization in agriculture
DTA ₁	Digital technologies enable more efficient management of agricultural holdings	0.8545	High consistency; strongly integrated within the construct	Efficient farm management represents a core component of digitization, enabling optimization of resources and processes
DTA ₂	The use of digital platforms facilitates access to information important for agricultural production	0.8327	Stable contribution; well aligned with other variables	Improved access to information supports data-driven decision-making and reduces uncertainty in agricultural activities
DTA ₃	Digitization contributes to better organization and planning of agricultural activities	0.8332	Strong and balanced contribution to the construct	Enhanced planning and organization facilitate systematic implementation of digital practices in agriculture
DTA ₄	The use of digital tools (apps, sensors, software, etc.) increases productivity in agriculture	0.8938	Highest value; dominant variable within the construct	Productivity growth is the key driver of digitization and the primary motivation for adopting digital technologies
DTA ₅	Digital technologies improve communication between farmers, markets and institutions	0.861	Very high consistency; significant integrative role	Strengthened communication improves coordination, market access, and institutional integration within the agricultural sector

Source: According to research data.

Table 7. presents a reliability analysis of the scale using Cronbach's alpha through the "alpha if item deleted" procedure, which assesses how the removal of individual items would affect the internal consistency of the construct measuring agricultural development.

The results indicate the following dimensions: The most important predictor is sustainable development based on technological progress (DPA₃); The developmental foundation is reflected in modernization and the introduction of new technologies (DPA₁ and DPA₂); The competitive dimension is represented by strengthening the sector's market position (DPA₄); The human factor is captured through farmers' willingness to adopt innovations (DPA₅).

Table 7. clearly indicates that the development of agriculture is primarily grounded in sustainable development driven by technological progress, followed by the modernization of production and improvements in productivity, while sectoral competitiveness and farmers' (agricultural entrepreneurs) willingness to adopt innovations represent key mediating factors in the overall process of agricultural development.

Table 7. Cronbach α Development of agriculture

Claim label	Claim description	Cronbach α (if omitted)	Contribution interpretation	Predictive significance for the development of agriculture
DPA ₁	The introduction of new technologies contributes to the long-term development of agriculture	0.7637	Stable consistency; well-integrated within the construct	Technological adoption represents a fundamental driver of long-term agricultural development
DPA ₂	The modernization of agriculture leads to an increase in productivity and production quality	0.757	Lowest but acceptable value; balanced contribution	Modernization enhances both efficiency and quality, forming a key pathway for sectoral advancement
DPA ₃	Technological progress has a positive effect on the sustainable development of agriculture	0.884	Highest value; dominant variable within the construct	Sustainability emerges as the central dimension of development, strongly driven by technological progress
DPA ₄	Modern approaches to production contribute to strengthening the competitiveness of the agricultural sector	0.7979	Strong contribution; strategically relevant dimension	Competitiveness reflects the market outcome of technological and organizational improvements
DPA ₅	The development of agriculture depends on the willingness of farmers to accept new technologies.	0.7554	Acceptable consistency; slightly lower integration	Human readiness and openness to innovation are critical enabling factors for development

Source: According to research data.

The obtained values of the Cronbach's α coefficient for all observed constructs range approximately from 0.75 to 0.89, indicating: good to very good internal consistency of the scales, a high level of homogeneity among the items within each construct and reliable measurement of latent variables related to the application of AI, digitalization, and agricultural development.

Accordingly, the use of the defined items is justified in further analysis of the relationships among the examined variables.

Results and Discussion

The results presented in the Table 8. indicate respondents' attitudes toward the defined variables measured using a five-point Likert scale.

Table 8. Respondents' attitudes towards stated statements of the given variables

Application of AI in agriculture	1	2	3	4	5
AIA ₁ - The application of AI enables more precise management of agricultural production	2	13	26	112	124
AIA ₂ - The use of systems based on AI contributes to increasing yields in agriculture	3	10	39	104	121
AIA ₃ - The application of AI reduces production costs in agriculture	2	17	51	101	106
AIA ₄ - Technologies based on AI enable more effective monitoring of the health status of plants and soil	2	15	31	94	135
AIA ₅ - AI has great potential for improving sustainable agricultural production	2	17	30	111	117
Digitization in agriculture	1	2	3	4	5
DTA ₁ - Digital technologies enable more efficient management of agricultural holdings	3	10	26	74	164
DTA ₂ - The use of digital platforms facilitates access to information important for agricultural production	3	6	28	78	162
DTA ₃ - Digitization contributes to better organization and planning of agricultural activities	3	6	28	79	161
DTA ₄ - The use of digital tools (apps, sensors, software, etc.) increases productivity in agriculture	7	28	58	96	88
DTA ₅ - Digital technologies improve communication between farmers, markets and institutions	35	58	184	0	0
Development of agriculture	1	2	3	4	5
DPA ₁ - The introduction of new technologies contributes to the long-term development of agriculture	5	6	31	94	141
DPA ₂ - The modernization of agriculture leads to an increase in productivity and production quality	9	12	35	78	143
DPA ₃ - Technological progress has a positive effect on the sustainable development of agriculture	9	46	56	70	96
DPA ₄ - Modern approaches to production contribute to strengthening the competitiveness of the agricultural sector	11	17	29	94	126
DPA ₅ - The development of agriculture depends on the willingness of farmers to accept new technologies.	5	6	35	79	152

Source: According to research data.

Overall, the distribution of responses shows a generally positive perception of modern technological solutions in agriculture, particularly in relation to the application of AI, digitization, and the broader development of the agricultural sector:

- *Application of AI in agriculture* - The results indicate a high level of agreement with statements related to the application of AI in agriculture. For most statements (AIA₁-AIA₅), the majority of responses are concentrated in categories 4 and 5, suggesting that respondents largely recognize the importance and potential of AI in agricultural production. Respondents particularly agree that AI enables more precise management of agricultural production (AIA₁), contributes to increasing agricultural yields (AIA₂), and has significant potential for improving sustainable agricultural production

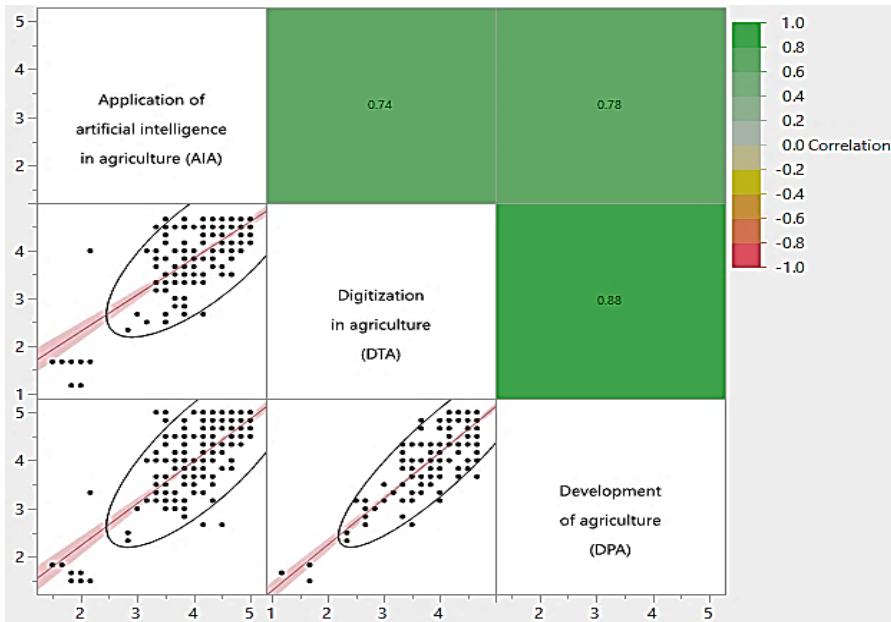
(AIA₅). Additionally, a high level of agreement with statements AIA₃ and AIA₄ suggests that respondents believe AI can contribute to reducing production costs and improving the monitoring of plant and soil health. These findings indicate a generally positive perception and a strong recognition of the role of AI in improving agricultural efficiency and sustainability.

- *Digitization in agriculture* - The results related to digitization in agriculture also show generally positive attitudes toward the use of digital technologies. Statements DTA₁, DTA₂, and DTA₃ show a strong concentration of responses in category 5, indicating that respondents believe digital technologies enable more efficient farm management, facilitate access to important agricultural information, and contribute to better organization and planning of agricultural activities. However, responses to statement DTA₄ are more evenly distributed across categories, suggesting a somewhat more cautious perception of the direct impact of digital tools such as computer applications, sensors, and software on productivity growth. A particularly notable result appears in statement DTA₅, where the majority of respondents selected the neutral option (3), while no responses were recorded in categories 4 and 5. This indicates that respondents are uncertain about the extent to which digital technologies currently improve communication between farmers, markets, and institutions. Overall, the findings suggest that while respondents recognize the importance of digitization, certain limitations or challenges in its practical implementation may still exist.
- *Development of agriculture* - The results related to the development of agriculture show a high level of agreement with statements linking technological innovation and modernization with agricultural development. Statements DPA₁, DPA₂, and DPA₅ show a dominant number of responses in categories 4 and 5. This indicates that respondents believe that the introduction of new technologies and farmers' willingness to adopt them represent the key factors for the long-term development of agriculture. Respondents also largely agree that modernization contributes to increased productivity and improved production quality (DPA₂), as well as to strengthening the competitiveness of the agricultural sector (DPA₄). Although statement DPA₃ shows a somewhat more dispersed distribution of responses, suggesting differing perceptions regarding the direct impact of technological progress on sustainable agricultural development, the overall results confirm that respondents strongly associate technological advancement with the future development of agriculture.

Taken together, the findings indicate that respondents demonstrate a positive perception of technological innovation in agriculture. AI and digital technologies are widely recognized as important tools for improving efficiency, productivity, and sustainability in agricultural production. At the same time, the results suggest that certain aspects of digitization particularly those related to communication and institutional connectivity may require further development and support. Strengthening digital infrastructure, improving access to technological solutions, and enhancing farmers' digital competencies could therefore play a significant role in maximizing the benefits of digital transformation in agriculture.

In next figure (Figure 6.) the Pearson correlation coefficients for all components of the theoretical model are presented. It is evident that all relationships among the components are positive, signifying a positive correlation.

Figure 6. Pearson's correlation coefficient



Source: Authors calculation.

The strongest correlation is observed between the independent components (DTA) and component (DPA), with a coefficient of 0.88, followed by the correlation between components (AIA) and (DPA), i.e. 0.78, also indicating a strong relationship. The weakest correlation is between the components (AIA) and (DTA), with a value of 0.74, but still reflecting a strong correlation.

The highest coefficient of determination is 0.6724, meaning that 67.24% of the variance in component (DPA) can be explained by component (DTA). The next highest coefficient of determination is 0.6084, indicating that 60.84% of the variance in component (DPA) can be explained by component (AIA), while the lowest coefficient of determination is 0.5476, signifying that 54.76% of the variance in component (DTA) can be explained by component (AIA).

The summary of fit (Table 9.) shows that the model achieved an R^2 value of 0.812036, indicating that 81.20% of the variation in agricultural development is explained by the two independent variables included in the model. The adjusted R^2 value of 0.810664 confirms the robustness of the model after adjusting for the number of predictors. The Root Mean Square Error value of 0.346048 suggests a relatively small prediction error, indicating that the model provides reliable estimates of agricultural development levels. The mean value of the response variable 4.1422599 further suggests that respondents generally perceive agricultural development positively.

Table 9. Summary of fit

RSquare	0.812036
RSquare Adj	0.810664
Root Mean Square Error	0.346048
Mean of Response	4.1422599
Observations	277

Source: Authors calculation.

The analysis of variance (ANOVA), (Table 10.) confirms that the regression model is statistically significant, with $F(2,274)=591.8641$, $p<0.0001$. This result indicates that the independent variables jointly have a significant impact on the dependent variable. Such findings are consistent with previous research highlighting the importance of technological innovation and digital transformation in the agricultural sector. For example, studies have shown that the adoption of digital technologies significantly contributes to improvements in agricultural productivity and innovation (Wang et al., 2024). Similarly, digital technology adoption has been linked to enhanced efficiency and improved decision-making among farmers (Peng et al., 2024).

Table 10. Analysis of variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	141.75049	70.8752	591.8641
Error	274	32.81128	0.1197	Prob > F
C. Total	276	174.56177		<0.0001

Source: Authors calculation.

The results of the multiple regression analysis indicate that the development of agriculture (DPA) is significantly influenced by the application of AI in agriculture (AIA) and digitization in agriculture (DTA). The overall regression model demonstrates a high level of explanatory power and statistical significance.

The parameter estimates in Table 11. provide further insight into the individual contributions of the independent variables. The coefficient for application of AI in agriculture (AIA) is 0.3177551, $p < 0.0001$, indicating a statistically significant positive relationship with agricultural development. This suggests that an increase in the use of AI technologies leads to improvements in agricultural development outcomes. AI applications enable more precise data analysis, predictive modelling, and optimized resource management, which ultimately enhance agricultural productivity and sustainability.

The coefficient for digitization in agriculture (DTA) is 0.7272008, $p < 0.0001$, which is considerably larger than the coefficient for artificial intelligence. This indicates that digitalization has a stronger impact on agricultural development within the model. The standardized beta values support this conclusion, as DTA $\beta = 0.672246$ demonstrates a stronger influence compared to AIA $\beta = 0.282134$. Digital technologies such as digital platforms, smart sensors, farm management systems, and data-driven tools play a crucial role in improving agricultural efficiency and enabling better production planning. Previous studies have also confirmed that digital technology adoption significantly contributes to agricultural productivity and farmers' income growth (Lei, Yang, 2024).

Additionally, the Variance Inflation Factor 2.2070171 for both predictors indicates that there is no serious multicollinearity problem in the model, suggesting that the independent variables provide distinct contributions to explaining the dependent variable.

Table 11. Parameter estimates

Term	Estimate	Std Error	t Ratio	Prob> t	Upper 95%	Std Beta	VIF
Intercept	-0.080388	0.129094	-0.62	0.5340	0.1737529	0	.
Application of artificial intelligence in agriculture (AIA)	0.3177551	0.043823	7.25	<0.0001	0.4040275	0.282134	2.2070171
Digitization in agriculture (DTA)	0.7272008	0.042091	17.28	<0.0001	0.810064	0.672246	2.2070171

Source: Authors calculation.

The lack-of-fit test (Table 12.) shows a statistically significant result. However, the relatively high maximum R^2 value of 0.9175 suggests that the model still captures most of the variability in the data. Residual and leverage plots further confirm that the regression assumptions are reasonably satisfied, and that the model predictions are consistent across the observed values.

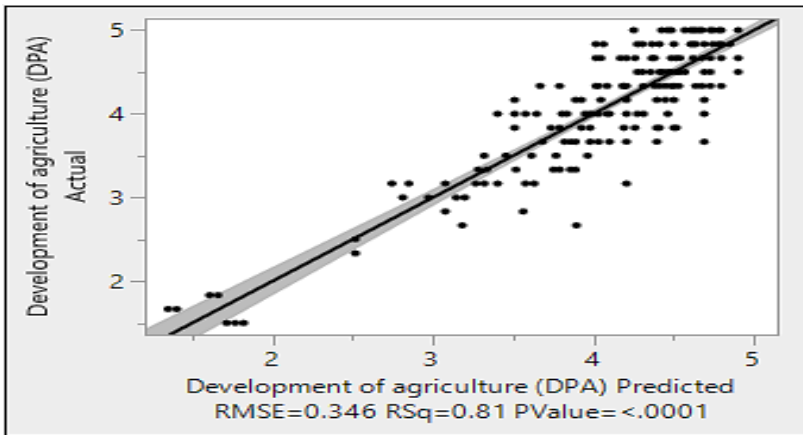
Table 12. Lack of fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack of Fit	85	18.409409	0.216581	2.8423
Pure Error	189	14.401871	0.076200	Prob > F
Total Error	274	32.811280		<0.0001
				Max RSq
				0.9175

Source: Authors calculation.

Overall, the results demonstrate that technological transformation plays a key role in agricultural development. The integration of AI and digital technologies enables farmers to optimize production processes, improve resource efficiency, and enhance decision-making based on real-time data. This finding aligns with previous research emphasizing that the combination of digital technologies and intelligent systems strengthens agricultural resilience and long-term sectoral development (Ke et al., 2025).

In summary, the findings confirm that both, AI and digitalization significantly contribute to agricultural development, with digitalization having a particularly strong influence. These results highlight the importance of promoting technological adoption in agriculture through policy support, farmer education, and investment in digital infrastructure, as these factors are essential for the sustainable modernization of the agricultural sector.

Figure 7. Actual vs Predicted plot

Source: Authors calculation.

Based on the information in Table 11., in Figure 7. is presented the high predictive validity and strong empirical support for the application of AI and digitization in agriculture having a statistically significant impact on the development of agriculture. In a practical sense, the chart confirms that the identified construct indicators are reliable and operationally usable for explaining and predicting the development of agriculture.

Conclusion

Based on the conducted analysis and in line with previous research, it can be concluded that technological innovations play a crucial role in the development of modern agriculture. The findings indicate that respondents have a positive perception of the application of artificial intelligence (AIA) and digital technologies (DTA) in agricultural production, recognizing their potential to enhance efficiency, productivity, and sustainability. The results highlighted the significant contribution of digital technologies to agricultural productivity and innovation. Through the adoption of digital technologies, efficiency and decision-making among farmers and agricultural entrepreneurs are improved.

The correlation analysis confirms strong positive relationships among all examined variables, particularly between digitization in agriculture (DTA) and agricultural development (DPA), indicating that higher levels of digital technology adoption are associated with greater agricultural development. Similarly, a strong correlation between artificial intelligence (AIA) and agricultural development (DPA) confirms that intelligent technologies contribute to optimized production processes and better decision-making.

Multiple regression analysis demonstrates that both independent variables (AIA) and (DTA) have a statistically significant positive effect on DPA. The high coefficient of determination of 0.812036 shows that 81.20% of the variance in agricultural development can be explained by these technological factors. Among the predictors, digitization exhibits a stronger influence $\beta(\text{DTA})$ 0.672246 compared to $\beta(\text{AIA})$ 0.282134, highlighting the critical role of digital platforms, smart sensors, and data-driven tools in improving agricultural efficiency. There is a positive effect of adopting digital technology on the productivity and income of all entities involved in agricultural entrepreneurship activities. The role of integrated digital and intelligent systems in stimulating the long-term development of agriculture is highlighted.

The results reject the hypothesis H_0 , which states that the application of AI and digitization in agriculture do not have a statistically significant impact on the development of agriculture (DPA). Both variables contribute significantly to explaining (DPA), with digitization showing a dominant effect.

Generally, these findings, supported by previous empirical studies, indicate that the integration of AI and digital technologies could be a key driver of agricultural modernization, resilience, and sustainable sectoral growth. They emphasize the importance of strengthening digital infrastructure, promoting technological adoption, and enhancing farmers' and agricultural entrepreneurs' digital competencies to maximize the benefits of technological transformation in agriculture.

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