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# ECONOMIC EFFICIENCY OF INTRODUCING DIGITAL TECHNOLOGIES IN AGRICULTURE

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**A R T I C L E I N F O.**

**Keywords:** digital technologies, agriculture, economic efficiency, key agricultural indicators, artificial intelligence, drone technologies, smart irrigation, sustainable development, productivity, resource conservation.

**Abstract**

This article analyzes the economic efficiency of introducing digital technologies into the agricultural sector of Uzbekistan. The impact of digitalization on productivity, resource efficiency, and export volumes is examined through the lens of global experience, specifically drawing on examples from China, the USA, and Germany. Focusing on the primary economic indicators of agriculture in the Samarkand region, a profound economic analysis was conducted regarding changes in crop yields, water and fuel conservation, production costs, and net profit following the implementation of digital solutions. Furthermore, the article highlights state programs within the framework of the "Digital Uzbekistan – 2030" strategy, discussing their economic benefits and future prospects in the agrarian sector. The results indicate that the adoption of digital technologies is a crucial factor in ensuring sustainable growth, resource optimization, and enhancing the export potential of Uzbekistan's agricultural sector.

## Introduction

In recent years, the implementation of digital technologies in agricultural sectors worldwide has been regarded as one of the most critical factors for sustainable development, ensuring food security, and the efficient use of resources. In digital agriculture, solutions such as artificial intelligence, drones, agrotechnical data analysis, and automated drip irrigation processes are widely used.

In the global economy in 2026, the share of the digital economy will be approximately 15.5% [1], which will amount to 16 trillion US dollars compared to the global nominal GDP of 108 trillion US dollars [2]. This figure showed that it has different values in different countries.

Specifically, "the scale of the digital economy in China amounted to 7.64 trillion US dollars, accounting for 42.8% of China's GDP, and the contribution of digital economy growth to GDP growth reached 66.45%" . These figures are expected to reach approximately 17% globally by 2028 [3], and the share of the digital economy in Southeast Asian economies is expected to reach ~56% of GDP by 2027, indicating the rapid development of online trade, payments, and digital services in the region [4]. Today, issues of ensuring food security, rational use of natural resources, and increasing production efficiency remain relevant on a global scale. Population growth, limited water and land resources, climate change, and rising production costs make it difficult to achieve high results in agriculture using traditional methods. Under these conditions, the introduction of digital technologies is emerging as the most effective means of modernizing the agricultural sectorDigital technologies - artificial intelligence, IoT sensors, GPS monitoring, drones, smart irrigation systems, electronic platforms, and agro-information systems - allow for real-time management of production processes, optimization of resource consumption, increased productivity, and reduced losses. As a result, the cost of production decreases, profitability increases, and competitiveness increases[5].

In Uzbekistan, there are problems such as water scarcity, land degradation, low labor productivity, and a lack of information in management. In particular, as agriculture holds a significant share in the country's GDP, employment, and exports, accelerating digitalization in the sector is becoming a strategic factor for economic growth[6]. Therefore, assessing the economic efficiency of implementing digital technologies in agriculture on a scientific basis is a requirement of today.The scientific and practical significance of this research is determined by several aspects: First, the study allows for the assessment of the economic results of implementing digital technologies—cost reduction, productivity growth, labor productivity growth, and increased profit and profitability—based on specific indicators. This serves as a scientific basis for the formation of agrarian policy;

Secondly, the developed methodologies and models can be applied to determine the effectiveness of digital solutions in farms, clusters, and agricultural firms, as well as to make investment decisions[7]. As a result, resource conservation and economic stability are ensured;

Thirdly, the research findings provide important practical recommendations for developing digital governance mechanisms at the regional level—especially for water-scarce regions (such as the Republic of Karakalpakstan or Samarkand region)[8]. This contributes to socio-economic development, employment, and increased export potential;

Fourthly, from a scientific perspective, the study enriches the theoretical foundations in a new direction where the agricultural economy and the digital economy intersect, and creates a methodological basis for future scientific developments in the field.

## Materials and Methods

During the preparation of this article, research materials, the results of scientific works of domestic and foreign researchers, as well as information from ministries, the National Statistical Committee, and international sources were used. The main materials were collected on the basis of statistical data and analyzed on the basis of available software. The obtained scientific conclusions are based on the results of scientific research. The research process involved the systematic collection, classification, and analysis of data using modern scientific methods. In particular, statistical analysis, comparative analysis, grouping methods, as well as dynamic and structural analysis techniques were applied. These methods made it possible to identify key development trends and assess the interrelationships and impact of various factors within the studied domain.

Empirical data were processed and analyzed using available software tools, including statistical and analytical programs. The use of such tools ensured the accuracy, reliability, and validity of the research findings.The scientific conclusions presented in this study are based on the results of thorough analysis and are grounded in both theoretical and empirical evidence. Furthermore, the proposed recommendations and conclusions are aimed at addressing existing problems and are supported by the findings of the research, highlighting their practical significance.

**Results and Analysis**

A newcomer to the global economy, the digital economy is reshaping industry worldwide, particularly the agricultural sector, at a very rapid pace. This contributes to a sharp increase in economic efficiency[9]. As a result of these processes, significant changes are observed in the volume and efficiency of agricultural production. In particular, farming systems managed on the basis of digital technologies contribute to increasing productivity. The dynamics of corn production indicators by country can be observed. As a result of these processes, the role of agriculture in the national economy is also changing significantly[10]. The implementation of digital technologies contributes to increasing production efficiency, the rational use of resources, and the sustainable development of the share of agriculture in the gross domestic product (GDP)[11]. The graph below shows the share of agriculture in GDP for various countries (Fig. 1).

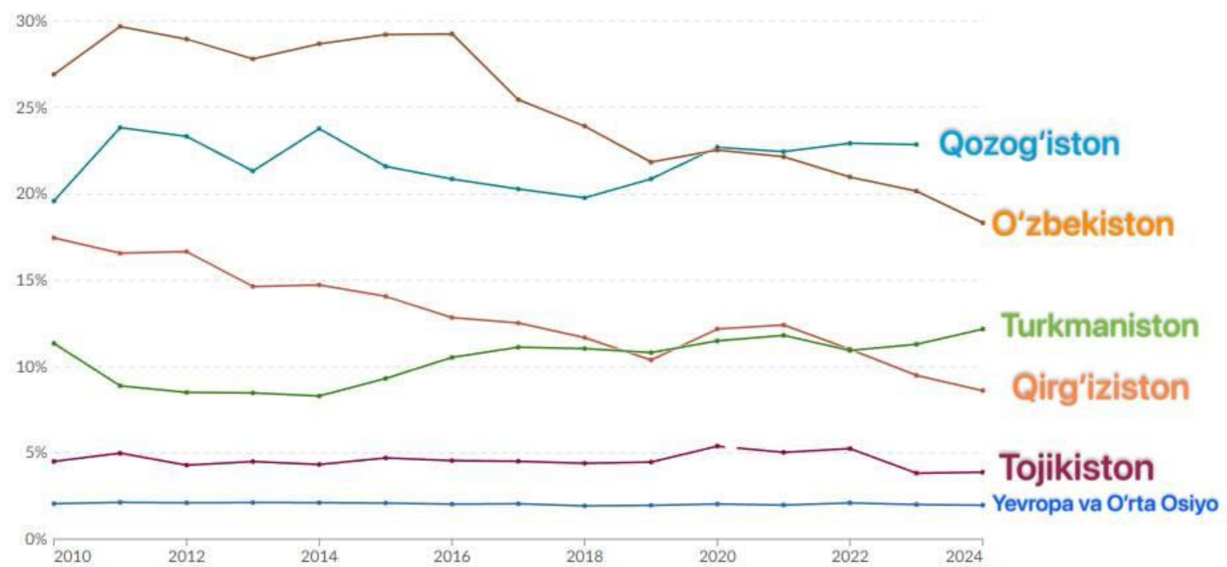


**Figure 1. Share of agriculture in GDP (2010-2024)**

The agricultural sector of the Republic of Uzbekistan contributes approximately 19.2% to the country's GDP and accounts for 5.8% of total export revenues [12], while employment stands at 13.88% . Therefore, the implementation of innovative technologies in the agricultural sector is of great importance for the country's economic security and food independence. In recent years, digital transformation processes in Uzbekistan have also been progressing rapidly. A number of state programs for the digitalization of the agricultural system, Presidential decrees and resolutions have been adopted[13].In his speeches, President Shavkat Mirziyoyev has repeatedly emphasized the need to modernize and digitalize agriculture. In particular, it states: "Developing agriculture based on digital technologies is the most correct way to rational use of water, land, and resources, increase productivity, and increase the income of farmers and dehkans" [14].

Another important law, the "Digital Uzbekistan - 2030" strategy, sets the task of widespread implementation of digital technologies in all sectors, including agriculture.The "Agricultural Development Strategy for 2020–2030" [15] identifies innovative technologies, agrotechnology, drones, digital mapping, and water-saving systems as key priorities. The state program "Water Resources Management and Development of the Irrigation Sector" for 2025–2028[16] provides for the use of drones in water accounting, monitoring, and management.Various theories and approaches to this field have been emphasized by several foreign scholars, including Robert Finger, Wenhuang Geng, and others. According to Robert Finger's theory, in his article "Digital Innovations for Sustainable and Resilient Agricultural Systems" [17], he demonstrated that digital technologies make agricultural systems more sustainable and resilient, increase productivity, and optimize resource use. Looking at an article written by Chinese researcher Wenxuan Geng, in his work "Digital Technologies Adoption and Economic Benefits in Agriculture: A Mixed-Methods Approach" [18], a positive correlation was found between the intensity of digital technology adoption and economic benefits; for example, it can be seen that income, productivity, and resource utilization efficiency increased through the implementation of technologies in the surveyed regions.

Analysis has shown that I believe the implementation of digital technologies in agculture will indeed serve to increase economic efficiency. But I am in favor of some additions to these ideas. The positive impact of digital technologies depends primarily on the territory, farm size, farmer qualifications, and infrastructure—that is, I want to say that the introduction of technology alone is not enough. As Finger said, the costs can also be seen, new equipment, programs, advanced training, that is, training service costs are necessary[19]. Additionally, there may be problems from the perspective of small-scale farmers, such as a lack of understanding of new technology or a lack of skills. The solution to this is to bring in a specialist who understands the new project well, along with the new technology. If we look at global research, as I mentioned above, we can look at the example of China. We have seen through experience how much the impact of agricultural digitalization has benefited the Chinese state economy. Scientists of our country have studied the effectiveness of using digital technologies in light industry enterprises in Uzbekistan. The results show that with the help of digital technologies, labor productivity increased by 70-80% and ICT (Information and Communication Technologies) costs decreased by 55% [20]. In developed countries, we can see that based on Chinese experience, agricultural production using digital technologies has increased and product productivity has increased. This situation has had a huge impact on the production of digital technologies developed in the countries of the world. The system of digitalization of agriculture exists not only in China, but also in the USA, Germany, and the Netherlands.

In our country, based on the decisions made by President Shavkat Mirziyoyev, a number of measures are being taken to increase the efficiency of agricultural production and products using digital technologies, which will bring great benefits to the economy of our country, Uzbekistan.

In addition to these, agriculture began to occupy an important place in the country's economy. According to Invest Uzbekistan, agriculture contributes approximately 19.2% to the country's gross domestic product (GDP) [21]. Uzbekistan has also developed a strategy for the development of agriculture for 2020-2030, and the creation of agricultural free economic zones in several regions will create favorable conditions for attracting investment into agribusiness and the agro-industrial complex. Uzbekistan has made significant progress in implementing digital technologies in agriculture, but to further develop this process and increase its economic efficiency, systematic work must be carried out in several areas. These include expanding internet coverage, developing high-speed mobile communication networks, especially in rural areas, and creating programs that automatically calculate crop forecasts, water consumption, and fertilizer rates based on artificial intelligence (AI). This will significantly help farmers, as artificial intelligence can predict this in advance. In particular, depending on the temperature of the sun, it determines drip irrigation, that is, when and how much water should be sent to the land. This, in turn, contributes to a significant improvement in crop yields. In addition, it is planned to include the subjects "Digital Agriculture" and "IoT Agronomy" in the curricula of agricultural universities and colleges.

One of the most profitable agricultural products in Uzbekistan is cotton raw materials, which were obtained by introducing digital technologies into agriculture established in Fergana. World Bank studies have shown that after the implementation of monitoring and digital tools, cotton yields increased by 75-80% [22].

One of the indicators that brings the greatest benefit to the economy of Uzbekistan is agriculture. Production efficiency and economic profit have significantly increased in the Samarkand region through the implementation of digital technologies in agriculture. According to the table data, digitalization has been implemented in stages since 2023, and its positive impact is reflected in the following indicators:

Agricultural sown areas reached 320,047 hectares in 2023, maintaining steady growth rates.

Agricultural production in 2023 reached 49,025.9 billion soums, showing significant growth compared to the previous year.

In particular, the volume of production in agriculture and animal husbandry increased and reached 26,331.1 and 22,694.8 billion soums, respectively.

Production growth rates also showed positive dynamics: 103.9% in agriculture and 103.5% in animal husbandry.

These indicators clearly prove the efficient use of resources, increased productivity, and increased labor productivity following the implementation of digital technologies. As a result, digitalization plays an important role in increasing the economic efficiency of the agricultural sector and bringing additional benefits to the regional economy.

**Table 1. Main indicators of agriculture in the Samarkand region**

| № | Indicators | Unit of measurement | Years | | | Change in 2025 compared to 2017 | |
|---|---|---|---|---|---|---|---|
| | | | 2017 | 2023 | 2025 | Miqdoriy, +/- | Nisbiy, % |
| 1. | Sown area of agricultural crops | gektar | 351249 | 320047 | 300491 | -50758 | 85,55 |
| 2. | Agricultural products | mlrd. so‘m | 21506,8 | 49025,9 | 60758,2 | 39251,4 | 2,8 marta |
| 3. | Agriculture | ming kishi | 13762,7 | 26331,1 | 29528,5 | 15765,78 | 2,1 marta |
| 4. | Animal husbandry | ming kishi | 7744,1 | 22694,8 | 31229,7 | 23485,6 | 4 marta |
| 5. | Growth rate of agricultural production, as a percentage of the previous year | % | 100,371 | 103,721 | 103,3 | 2,99 | 102,92 |

As seen from the data in Table 1, significant structural and qualitative changes occurred in the agricultural sector of the Samarkand region between 2017 and 2025. In particular, despite the reduction of agricultural land by 14.5%, the total volume of production increased by 2.8 times. This situation indicates an increase in the efficiency of land resource use and the priority of intensive factors in production.

Significant growth rates were also observed in the fields of agriculture and animal husbandry, with high dynamics especially noted in the livestock sector. This confirms that production volumes and economic efficiency have increased as a result of the gradual introduction of modern management methods, innovative agricultural technologies, and digital technologies[23].

Overall, during the period under review, a process of transition from an extensive development model to an intensive and technologically based stage of development is being observed in agriculture. As a result, the possibilities of more rational use of available resources, increasing labor productivity and increasing the volume of gross output have expanded.

**Table 2. Regression analysis of the main agricultural indicators of the Samarkand region**

| Year | Area_hectare | total_product_billion | farmer | livestock_man | texnologiya |
|---|---|---|---|---|---|
| 2010 | 372824.0 | 5368.6 | 3577.2 | 1791.4 | 0 |
| 2011 | 353246.0 | 6744.0 | 4329.5 | 2414.5 | 0 |
| 2012 | 331287.0 | 7808.6 | 4812.1 | 2996.5 | 0 |
| 2013 | 360247.0 | 9477.7 | 5831.5 | 3646.2 | 0 |
| 2014 | 364253.0 | 11747.6 | 6974.1 | 4773.5 | 0 |
| 2015 | 360227.0 | 14300.0 | 8949.4 | 5350.6 | 0 |
| 2016 | 358967.0 | 17088.6 | 10592.9 | 6495.7 | 0 |
| 2017 | 351249.0 | 21506.8 | 13762.7 | 7744.1 | 0 |
| 2018 | 351833.0 | 25658.0 | 15035.3 | 10622.7 | 0 |
| 2019 | 328107.0 | 28379.5 | 15445.4 | 12934.1 | 0 |
| 2020 | 340750.0 | 33759.4 | 18331.4 | 15428.0 | 0 |
| 2021 | 359283.0 | 41206.1 | 22333.7 | 18872.4 | 0 |
| 2022 | 336799.7 | 42088.9 | 21472.0 | 18956.0 | 0 |
| 2023 | 320047.0 | 49025.9 | 26331.1 | 22694.8 | 1 |
| 2024 | 325659.0 | 56830.8 | 30688.6 | 26142.2 | 1 |
| 2025 | 300491.0 | 60758.2 | 29528.5 | 31229.7 | 1 |

Based on the data in Table 2, the Stata program was used to conduct statistical and econometric analyses of the study. Stata is professional software designed by StataCorp that enables data processing, statistical calculations, and regression model evaluation. Using this program, descriptive statistics, comparative analysis, and regression assessments are performed.

The primary objective of this study is to evaluate the impact of the introduction of digital technologies on key agricultural indicators during the period 2010–2025 using econometric methods.

Since 2023, digital technologies have been implemented in the industry (technology = 1), whereas in 2010-2022, the technology is absent (technology = 0).

The following methods were used during the analysis process.

• Comparative analysis (Before-After Analysis)

• Analysis of differences in mean values

• Simple regression model (OLS)

Basic regression model $\mathbf{Y_t=\beta_0+\beta_1 * Tech_t+\varepsilon_t}$ this is how it is structured.

$\mathbf{Y_t}$ — gross agricultural output (mlrd so‘m).

$\boldsymbol{\beta_0}$ — non-technological gross output (mlrd so‘m).

$\boldsymbol{\beta_1}$ — technology implementation (0 yoki 1).

$\mathbf{Tech_t}$ — economic impact of technology

$\boldsymbol{\varepsilon_t}$ — random error.

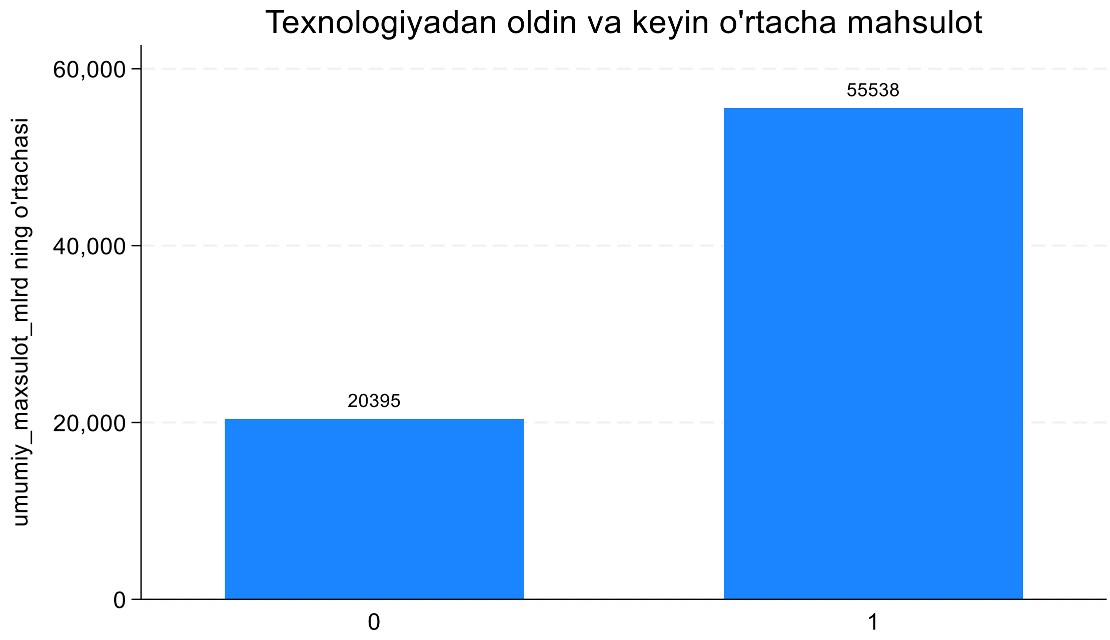


**Figure 2. Average production volume before and after technology (mlrd so‘m)**

While the average output was 20,395 billion before the technology was implemented, this figure reached 55,538 billion after its implementation.

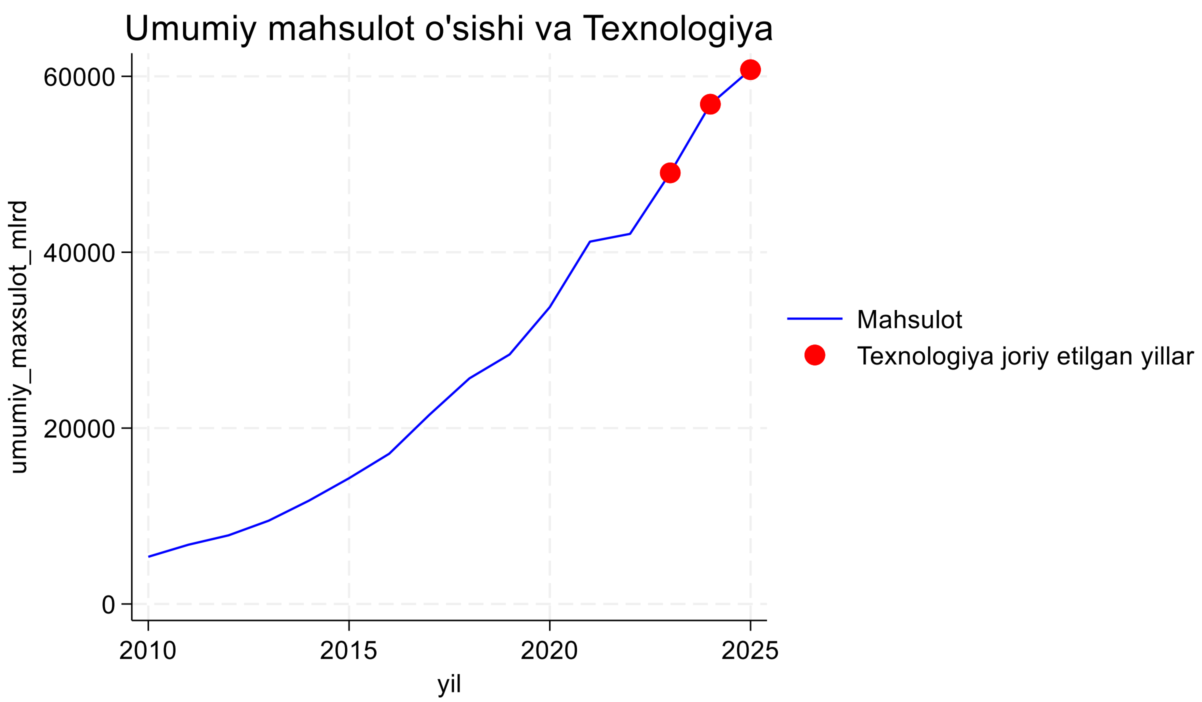


**Figure 3. Gross product growth graph.**

The graph in Figure 3 reflects the growth dynamics of gross agricultural output for the period from 2010 to 2025. Analysis of the graph shows that between 2010 and 2022, the volume of product production grew at a stable but steady rate[24]. However, starting from 2023, as a result of the introduction of technological innovations (marked with red dots on the graph), it can be seen that the volume of production has shifted to a sharp growth trajectory. In particular, in 2022, the volume of production amounted to 42,088.9 billion soums, and by 2025, with the use of technology, this figure reached 60,758.2 billion soums. This confirms that the transition from traditional methods to technological ones increases production efficiency multiplicatively.

Comparison of mean values (Means) in the analysis of T-test results in Figure 4. Group 0 (Technology-free period), the average total product over 13 years of observation (2010–2022), amounted to 20,394.9 billion soums.

Group 1 (Period of Technology Implementation), during the 3-year period (2023–2025), average output rose sharply, reaching 55,538.3 billion soums.

Difference (Diff), as a result of the introduction of technology, the volume of production increased by an average of 35143.4 billion soums.

Two-sample t test with equal variances

| Group | Obs | Mean | Std. err. | Std. dev. | [95% conf. | interval] |
|---|---|---|---|---|---|---|
| 0 | 13 | 20394.91 | 3569.483 | 12869.95 | 12617.67 | 28172.14 |
| 1 | 3 | 55538.3 | 3447.929 | 5971.987 | 40703.06 | 70373.54 |
| Combined | 16 | 26984.29 | 4595.927 | 18383.71 | 17188.31 | 36780.28 |
| diff | | -35143.39 | 7767.609 | | -51803.26 | -18483.53 |

diff = mean(0) - mean(1)     t = -4.5244
H0: diff = 0     Degrees of freedom = 14

Ha: diff < 0     Ha: diff != 0     Ha: diff > 0
Pr(T < t) = 0.0002     Pr(|T| > |t|) = 0.0005     Pr(T > t) = 0.9998

Two-sample t test with equal variances

| | obs1 | obs2 | Mean1 | Mean2 | dif | St_Err | t_value | p_value |
|---|---|---|---|---|---|---|---|---|
| umumiy_maxsulot_mlrd~g 0 1 | 13 | 3 | 20394.91 | 55538.3 | -35143.39 | 7767.609 | -4.5 | .0005 |

**Figure 4. Analysis of T-test results (T-test).**

The results of the two-sample t-test analysis show that the application of technologies in agriculture has had a significant positive impact on the total production volume. According to statistical data, the average production before the introduction of the technology amounted to 20394.9 billion soums, and in the years when the technology was used, this figure reached 55538.3 billion soums. The difference between the two periods amounted to 35,143.4 billion soums, which is statistically significant at a level of p=0.0005. This confirms that technological modernization in the field under study has served to increase efficiency by more than 2.7 times.

The results of the regression analysis in Table 3 indicate a high degree of model adequacy (R2=0.98). This means that almost all variability in the dynamics of agricultural production (98%) is explained by selected factors. The high value of the F-statistic (F=313.15) confirms the statistical reliability of the model. In the study, the coefficient of the technological factor has a positive value (9060.75), which is significant at a level of $p < 0.01$. This means that the introduction of technological innovations will contribute to a significant increase in production volume (averaging 9,060.7 billion so'm).

**Table 3. Regression analysis of the main agricultural indicators of the Samarkand region**

| Umumiy_maxsulot_mlrd | Coef. | St.Err. | t-value | p-value | [95% Conf | Interval] |
|---|---|---|---|---|---|---|
| texnologiya | 9060.749 | 2451.767 | 3.70 | .003 | 3764.029 | 14357.468 |
| yil | 3260.33 | 207.593 | 15.71 | 0 | 2811.854 | 3708.807 |
| Constant | -6552431.2 | 418507.51 | -15.66 | 0 | -7456561.8 | -5648300.7 |

| | | | |
|---|---|---|---|
| Mean dependent var | 26984.294 | SD dependent var | 18383.709 |
| R-squared | 0.980 | Number of obs | 16 |
| F-test | 313.158 | Prob > F | 0.000 |
| Akaike crit. (AIC) | 302.261 | Bayesian crit. (BIC) | 304.579 |

**** p<.01, p<.05, p<.1*

**Conclusion**

An analysis of the main agricultural indicators of the Samarkand region for 2010–2025 (Table 1) shows that significant structural changes and dynamic growth have been observed in the sector in recent years. Based on these analytical data, the following scientific and practical conclusions were drawn.- Growth in production volume and structural stability. Over the past period, the total value of agricultural products increased from 5,368.6 billion soums in 2010 to 60,758.2 billion soums by 2025. In particular, the share of the livestock sector is steadily growing in parallel with agriculture, which indicates the successful implementation of diversification processes in the sector.

- Efficiency of land resource use. Although the total area of sown areas (averaging 330,000–360,000 hectares) has not changed significantly, a several-fold increase in production volumes indicates an increase in the efficiency of intensive farming and agrotechnical measures. This proves that it is possible to maximize benefits from limited resources through the implementation of digital technologies (smart irrigation).

- The necessity of digital monitoring. The fluctuations in growth rates over the years in the table (for example, the decline rate in 2018 was 94.1%) indicate the dependence of agriculture on climate and external factors. To mitigate such risks, it is of strategic importance to establish a real-time forecasting system using agroanalytical systems and GPS monitoring.

Based on the results obtained (Table 1), it is considered expedient to implement the "Agrosanoat" concept into the agricultural production chain not only in the Samarkand region but throughout the republic in the future, specifically through artificial intelligence-based productivity forecasting models. The adoption of these measures will serve as a guarantee for ensuring sustainable economic growth and food security in the period after 2025.

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