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RESEARCH ARTICLE
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Management of Agricultural Innovations: A Role for Global Food Security

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ABSTRACT

Food security is a critical global issue, and searching for new solutions is particularly relevant. This study aimed to evaluate existing approaches to fostering innovation in agriculture. The study examined statistical data reflecting the development of innovation in Kazakhstan. The findings emphasized the vital role of agriculture in Kazakhstan's economy and, highlighted the importance of innovation in this sector to enhance competitiveness both internationally and domestically. By analyzing the data, the study concluded that the situation in Kazakhstan regarding the adoption of innovative technologies, particularly in agriculture, has improved. Additionally, the research presented trends in the enhanced functioning of agriculture, especially in terms of increased crop yields and livestock production. Based on the current context and the need for further technological development, the study proposed recommendations for public policy aimed at achieving key objectives in this area. The insights gained from this research can be applied to shaping national policies and guiding the long-term development strategies of individual enterprises.

Keywords: Digital technologies; State support; Sustainable development; Entrepreneurship; Macroeconomics.

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INTRODUCTION

Agriculture plays a crucial role in the development of the country for various reasons, with food security being the primary one (Zafar et al., 2024). It lies in having the capacity to provide food for the country's population, which is a fundamental aspect of national security (Winkler et al., 2023). In other words, this sector plays a strategically significant role in the country's development, comparable to that of other economic sectors like oil. The agricultural sector underlies the development of other economic sectors, such as food processing, logistics, raw material processing, and manufacturing, especially for developing countries (Zafar et al., 2023). This industry has the potential to create numerous jobs and improve the standard of living in rural areas. Considering all this, special attention needs to be paid to this industry. With the passage of time and the development of the latest technologies, it is increasingly important to introduce innovations in the agricultural sector as well (Zafar et al., 2022). This is due to the significant influence of the latest technology on various aspects of agriculture's development. They are layered enough to improve product quality, improve productivity, and increase the optimization of resource management (Arstambekova, 2023). Nevertheless, given the significant role those innovative technologies play in gaining a competitive advantage, it is crucial to identify new opportunities to apply the latest technologies in this field and ensure their implementation remains relevant (Shoukat et al., 2024).

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In the Republic of Kazakhstan, agriculture, among other things, is one of the main components of the development of the local economy. In this context, it is crucial to identify opportunities for the application and development of cutting-edge technologies within Kazakhstan's industry. The opportunities for the development of innovative technologies in the sphere of agriculture in Kazakhstan have been investigated by quite a few researchers. Sousa et al. (2021) noted that although the development of innovative technologies in the industry leads to positive results for the state and enterprises in general, it can also cause many difficulties, especially due to the lack of competence of managers responsible for the implementation of such investments. In this regard, researchers have offered certain recommendations to avoid such difficulties in introducing the latest technologies in enterprises. Tokhayeva et al. (2020) addressed the positive trends observed in the context of achieving food independence in the country and also formed certain recommendations for improving the situation (specifically regarding public policy). Arstambekova (2023) recommended the implementation of some principles in the context of agricultural production, namely integrated innovation structures, innovation-orientated value chains, and flexible organizational structures, along with changes in the context of industry regulation.

Kurmanova et al. (2021) provide a comprehensive list of recommendations aimed at fostering agricultural growth, emphasizing not only the role of innovation but also the need for regulatory frameworks that encourage sustainable practices and efficient resource utilization. Their recommendations span various aspects of the agricultural process, from pre-harvest to post-harvest stages, underscoring the importance of cohesive policy support, structured subsidies, and access to cutting-edge technologies to drive productivity and resilience within the sector. Seitzhanov et al. (2020) further underscore the critical role of public authorities' involvement in promoting agricultural development. They argue that state intervention is not merely supportive but essential in establishing a foundation for innovation and sustainable growth. According to their research, financial incentives, favorable policies, and technical assistance are necessary for farmers to adopt new methods and technologies. The authors suggest specific policy mechanisms, such as subsidies for technology acquisition and grants for research in sustainable agriculture that would enable the sector to modernize more effectively. Kuralbayeva et al. (2023) highlight the agro-industrial sector's need for systematic and strategic improvements to maintain long-term productivity and competitiveness. Their work emphasizes advanced technological solutions, such as precision farming, smart farming systems, and controlled environment agriculture (e.g., greenhouses). These methods are lauded for their potential to optimise yields and reduce resource waste, particularly in a country with varied climatic conditions like Kazakhstan. Denissova and Born (2021) contribute to the discussion by focusing on the role of innovation as a catalyst for the sector's development, specifically within the context of Kazakhstan. Their research explores the introduction of modern technologies such as automation, artificial intelligence, and biotechnology. They discuss how these innovations could transform Kazakhstan's agricultural landscape by making it more competitive on a global scale.

As the above analysis suggests, although researchers have considered the possibility of introducing the latest technologies in agriculture in Kazakhstan, they have not sufficiently described the trends observed in the introduction of innovations in the industry and have not used a considerable statistical base to form conclusions of this kind. This study aimed to evaluate the approaches applied in the Republic of Kazakhstan for technology development, with a focus on both general advancements and those specific to the agricultural sector. The objectives of the study were to identify opportunities for developing approaches aimed at improving the level of agricultural innovation, the impact of innovative technologies in the sector on sustainable development, and to provide recommendations for building long-term policies in this area to ensure global food security.

MATERIALS & METHODS

Within the framework of this study, a comprehensive analysis of statistical information assessing the state and development of both innovation and agriculture in Kazakhstan was conducted. The period of the analysis was 20 years: from 2003 to 2023. The Bureau of National Statistics of the Agency for Strategic Planning of the Republic of Kazakhstan (2024) provided data on domestic research and development (R&D) expenditure and its share in the gross domestic product, the number of employees performing R&D, the number of organizations operating in this field, the share of innovative products in the GDP, and the volume of innovative products.

For a more accurate understanding of the real trends in the development of these areas, the data characterizing the volume of development and output of innovative products were analyzed considering inflation, information on which in Kazakhstan was taken from the Statista (2024) website. Re-estimating the data with inflation helped to note more real trends in some areas: without adjusting for inflation, the level of growth of the variables would have been much higher than it is, which makes the analyses carried out based on such data irrelevant. To analyze the data, an assessment of trends in the development of the latest technologies in the country was used, which helped to identify the key stages and moments that facilitated or hindered the development of innovation and the agricultural sector. It also helped to identify the interrelationships between political and economic changes in the country and their impact on agricultural development and innovation. The study also used correlation analysis to examine the relationships between R&D expenditure, the number of R&D organisations and employees, innovative production volume, agricultural yields, and other indicators assessed. The calculations and constructions were conducted using Microsoft Excel, especially for constructing the correlation matrix and drawing respective conclusions from it.

Furthermore, the study analyzed data in the context of agricultural developments in Kazakhstan, information on which was also taken from the Bureau of National Statistics of the Agency for Strategic Planning of the Republic of Kazakhstan (2024). To assess the effectiveness of approaches related to the introduction of innovations in the agricultural sector of the country, agricultural performance indicators were analyzed. Specifically, changes in the yield level of each of the main crops in crop production (cotton, sugar beet, open field vegetables, small crops, potatoes, and cereals), as well as absolute output indicators in livestock production (eggs, wool, and milk), were investigated. For crop production, the yield indicator was chosen since the efficiency of agricultural functioning can be assessed by how much crop can be obtained from one hectare of land. This indicator most accurately reflects the level of innovation used in the sector. For livestock production, an analogous approach would be incorrect, and therefore output data were used.

RESULTS

Kazakhstan's agricultural development is characterized by unique features, such as a substantial land area dedicated to this industry and the presence of diverse climatic zones that facilitate the cultivation of a wide range of products. This industry plays a significant role in the country, contributing considerably to gross domestic product, employment generation, rural development, and exports. Kazakhstan is actively introducing the latest technologies in agriculture, including digital technologies, satellite monitoring, and precision farming systems, which increase crop yields and production efficiency. Furthermore, in light of climate change and the need to rationalize the use of natural resources, Kazakhstan has been making efforts to develop sustainable agriculture. This includes measures to conserve soil, manage water resources, and reduce greenhouse gas emissions. The national government is actively fostering modernization and growth in the agricultural sector through a range of supportive measures, including subsidies, development programs, credit options and other strategic initiatives. These efforts are specifically designed to enhance industry competitiveness, stimulate investment, and accelerate the adoption of advanced technologies. Fig. 1 provides data illustrating the progress and impact of these technological advancements within the country's agricultural development.

As illustrated in Fig. 1, R&D expenditure in Kazakhstan has generally risen over the selected period. However, its share of the domestic product has declined, indicating that other sectors are developing at a faster rate than advanced technology initiatives. This trend highlights a pressing need for increased focus on R&D to bolster technological advancement within the country. Fig. 2 presents additional data, detailing the number of organizations and employees engaged in this sector and highlighting the current capacity and workforce dedicated to R&D in Kazakhstan.

Fig. 2 demonstrates a steady increase in both the number of organizations and employees within the R&D sector, indicating positive growth trends in Kazakhstan's innovation landscape. This upward trajectory reflects the nation's ongoing commitment to fostering innovation and expanding its technological capacity. Fig. 3 provides further insights, showing data on the volume of innovation output and its proportion relative to the gross domestic product, offering a broader view of the sector's economic impact.

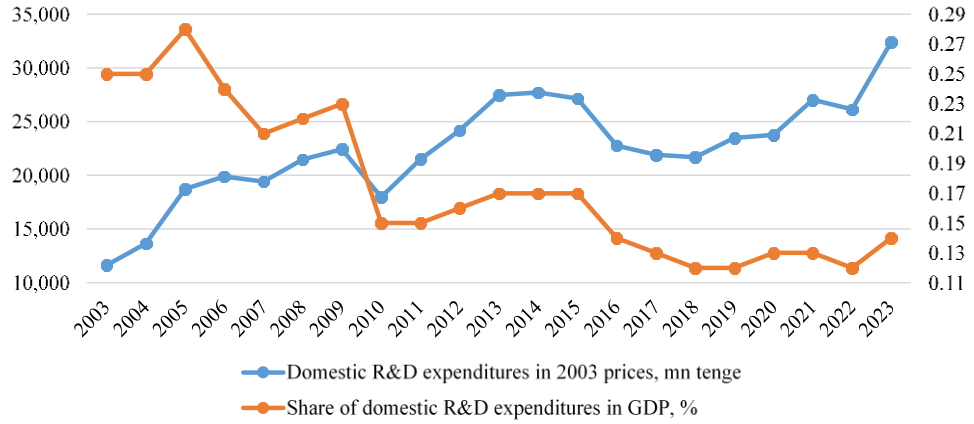

Fig. 1: Data on domestic R&D expenditure in Kazakhstan, adjusted for inflation and its share in gross domestic product. Source: compiled by the authors of this study based on data from the Bureau of National Statistics of the Agency for Strategic Planning of the Republic of Kazakhstan (2024) and Statista (2024).

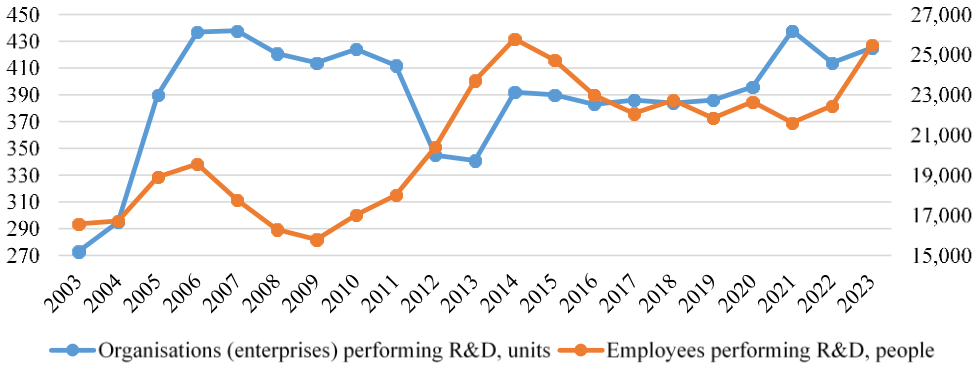

Fig. 2: Number of employees performing R&D as well as organizations in this field in 2003–2023; Source: compiled by the authors of this study based on data from the Bureau of National Statistics of the Agency for Strategic Planning of the Republic of Kazakhstan (2024).

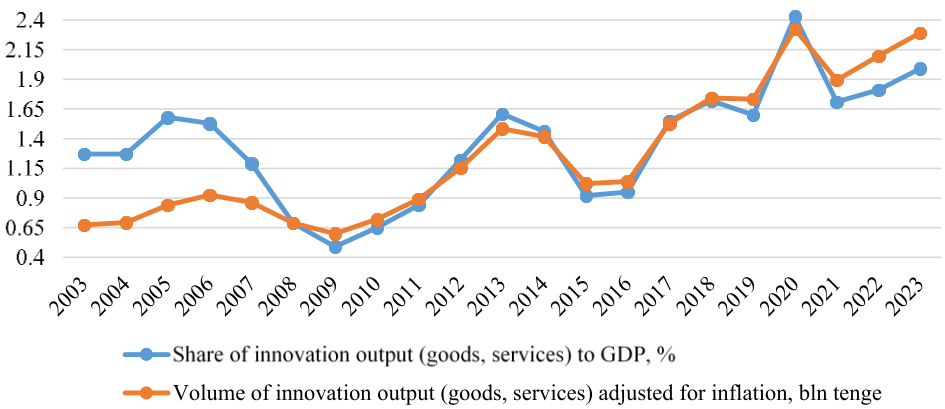

Fig. 3: Data on the share of innovation output to gross domestic product and inflation-adjusted innovation output in Kazakhstan from 2003 to 2023. Source: compiled by the authors of this study based on data from the Bureau of National Statistics of the Agency for Strategic Planning of the Republic of Kazakhstan (2024).

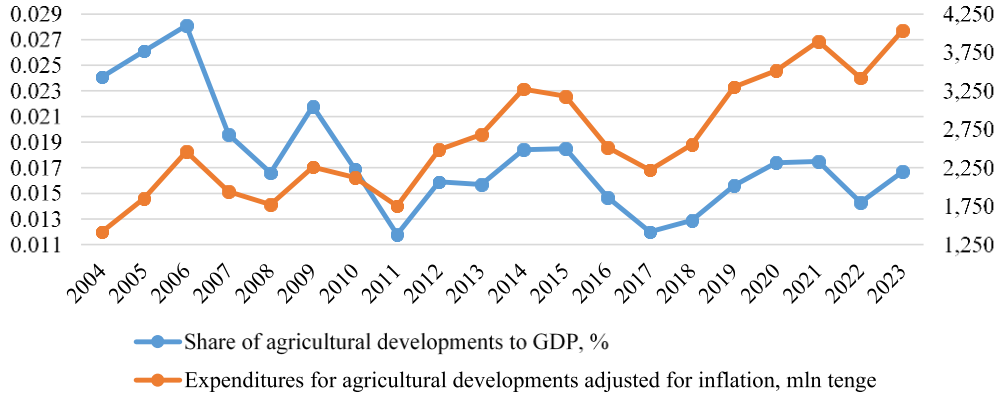

Fig. 4: Data in the context of agricultural developments in Kazakhstan from 2004 to 2023. Source: compiled by the authors of this study based on data from the Bureau of National Statistics of the Agency for Strategic Planning of the Republic of Kazakhstan (2024).

Fig. 3 illustrates a general upward trend in both the share of innovative products relative to gross domestic product (GDP) and the volume of products produced, even after adjusting for inflation. This suggests that Kazakhstan's innovative landscape is gradually improving. However, it is important to focus specifically on sectoral analyses, particularly within agriculture, to understand the dynamics in this critical area. Fig. 4 presents detailed data on innovation development within the agricultural sector, offering a closer look at the progress and challenges faced in this domain.

Fig. 4 shows a general increase in expenditure on innovation within Kazakhstan's agricultural sector, indicating ongoing activity in this area. However, the cost-to-GDP ratio has steadily declined over the period and remains relatively low. This suggests that the rate of growth in development costs for agriculture is slower compared to other sectors of the economy, highlighting the need for increased attention and investment in this field. To gain a more comprehensive understanding of the sector's performance, it is essential to examine specific indicators, such as agricultural yield, which provides a direct measure of efficiency. These data are presented in Table 1.

Table 1 shows that the yield of absolutely all types of crops in Kazakhstan has increased. This indicates that the country is gradually introducing new technologies into the industry, which allow harvesting more efficiently and utilizing the land stock better. The efficiency of operation for livestock production cannot be assessed in an analogous way, which is primarily caused by the specific features of the industry (it is comparatively more difficult to get more meat from one bird than it is at all possible). Table 2 provides a comprehensive assessment of the efficiency of livestock production in Kazakhstan, focusing on net output data as a key indicator of industry performance. Unlike crop production, where yields can be directly compared and assessed through output per unit of land, livestock efficiency is more complex due to the biological constraints and varied production processes inherent to animal farming.

As Table 2 shows, the production volumes in the livestock sector as a whole are also increasing, which indicates the development of the sector and an increase in the efficiency of its functioning. Considering the correlation matrix of all the indicators that were used within the framework of the study, many of them have quite high values. In many cases, this is due to the remarkable closeness of these indicators: for example, innovation spending increases employee numbers. However, there is a noticeable correlation between yield levels and livestock output indicators. There is a particularly prominent level of correlation between these indicators and the share of domestic R&D expenditures, suggesting that the increasing role of innovative technologies in the development of agriculture (and the country as a whole) has a positive effect on the industry.

Agriculture is crucial in the poorest countries, providing food, reducing hunger, and contributing to economic development by creating jobs, particularly in rural areas. It also helps alleviate poverty, increases incomes, and supports exports, improving foreign exchange earnings and trade balances (Muoneke et al., 2022; Zou et al., 2022). Additionally, agriculture promotes social development by offering employment, education, and healthcare access in rural regions.

Table 1: Data in the context of individual agricultural crop yields in Kazakhstan from 2004 to 2023

Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Cotton yield, 100kg/ha	21.3	23.1	22.2	22.1	18.2	19.6	17.9	21.8	26.2	28.7
Sugar beet yield, 100kg/ha	197.4	209.2	240.8	248.9	204.3	182.9	174.3	188.2	168.2	267.7
Yield of outdoor vegetables, 100kg/ha	186	196	201	211	204	218.7	214.4	222.9	234	238.7
Yield of oilseed crops, 100kg/ha	6.2	7	6.6	7.2	5.5	6.5	5	6.7	6.1	8
Potato yield, 100kg/ha	134	150	153.6	155.8	143.7	160	143	167.2	165.9	181.5
Grain (including rice) and legume crop yields, 100kg/ha	8.8	10	11.7	13.3	10.1	12.6	8	16.9	8.6	11.6
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Cotton yield, 100kg/ha	25.1	27.8	26.2	24.4	25.9	26.2	25.9	26.4	28.7	28.1
Sugar beet yield, 100kg/ha	240.6	232.5	285.5	274.4	305.3	324.5	323.2	275.5	341.4	379
Yield of outdoor vegetables, 100kg/ha	243	245.8	250	253.7	257.3	260.5	265.9	268	271.3	274.6
Yield of oilseed crops, 100kg/ha	7.8	8.1	9.6	9.7	9.7	9.3	9.5	8.3	9.1	8.8
Potato yield, 100kg/ha	184.3	185.5	190.4	194.2	197.9	203.4	206.7	207.4	205.4	205.5
Grain (including rice) and legume crop yields, 100kg/ha	11.7	12.7	13.5	13.4	13.5	11.4	12.8	10.4	13.8	10.3

Source: compiled by the authors of this study based on data from the Bureau of National Statistics of the Agency for Strategic Planning of the Republic of Kazakhstan (2024).

Table 2: Data on the volume of livestock production in Kazakhstan from 2003 to 2022

Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Eggs of all kinds, mln pcs	2,277	2,317	2,514	2,495	2,664	2,989	3,306	3,720	3,719	3,673
Wool of all types, tonnes	26,782	28,499	30,444	32,389	34,172	35,249	36,428	37,635	38,455	38,437
Milk of all types, thsd tonnes	4,317	4,557	4,749	4,926	5,073	5,198	5,304	5,381	5,233	4,852
Slaughtered in production and sold meat in slaughter weight, thsd tonnes	614	654	676	725	752	778	794	834	838	845
Eggs of all kinds, mln pcs	3,896	4,291	4,737	4,757	5,103	5,591	5,531	5,066	4,838	5,052
Wool of all types, tonnes	37,638	37,779	38,025	38,518	38,980	39,166	39,492	40,210	41,199	41,582
Milk of all types, thsd tonnes	4,930	5,068	5,182	5,342	5,503	5,686	5,865	6,051	6,247	6,368
Slaughtered in production and sold meat in slaughter weight, thsd tonnes	871	900	931	961	1,018	1,060	1,121	1,169	1,231	1,241

Source: compiled by the authors of this study based on data from the Bureau of National Statistics of the Agency for Strategic Planning of the Republic of Kazakhstan (2024).

Agriculture plays a vital role in achieving the Sustainable Development Goals, particularly by addressing hunger, unemployment, and malnutrition (Candemir et al., 2021). However, the industry also generates significant waste, which renders adopting new technologies essential for environmental sustainability (Viana et al., 2022; He et al., 2021). Sustainable farming practices, including minimizing chemicals and enhancing biodiversity, help protect ecosystems and mitigate climate change by increasing carbon sequestration and reducing greenhouse gas emissions (Leonidou et al., 2020). There are several major trends in the context of technology development in agriculture. One of them is precision farming, which involves the use of drones and satellites to monitor crop health, soil moisture levels, plant disease, and pest detection. The same goes for the introduction of agrobots: autonomous harvesting robots, as well as other robotic and automated machines. Genetic and biotechnologies, such as the development of genetically modified crops that are resistant to disease and unfavorable climatic conditions, and the use of CRISPR technology for genome editing, also offer new opportunities to improve plant and animal performance, even though certain consumer groups may still consider them dangerous (Haroon et al., 2022; Firdous et al., 2024; Kamal et al., 2024). Certain types of plant cultivation, such as hydroponics, aquaponics, and vertical farming, are gaining popularity. Hydroponics allows plants to grow without soil, using nutrient solutions to reduce water costs, while aquaponics combines fish farming with plant cultivation, using fish waste as fertilizer. Vertical farming growing plants in multi-layered structures, optimizes space and resources, supporting year-round production. Sustainable farming practices, including crop rotation and the use of natural pest control, also contribute to environmental safety (Zahra et al., 2024).

Based on the data and analysis, several key recommendations for agricultural innovation in Kazakhstan are proposed. These include increasing investment in new technologies, promoting digital solutions to improve efficiency and yields, and offering training programs for farmers. The government should provide more subsidies and grants for innovative projects, encourage public-private partnerships and enhance infrastructure and market access. By implementing these measures, Kazakhstan can strengthen its agricultural sector, driving economic growth and sustainability.

DISCUSSION

This study examined agricultural development in Kazakhstan, highlighting its vast agricultural areas and diverse climatic zones. Given the sector's importance, continuous state support, especially for innovative technologies, is essential for long-term sustainability. The proposed approaches are critical for addressing ecological and food security challenges. The study also explored emerging agricultural technologies, particularly genetically modified products, which can significantly contribute to tackling global food insecurity. Qaim (2020) emphasized that new plant breeding technologies (NPBTs) offer great potential for sustainable agriculture and food security. While past breeding efforts have helped address hunger, they also reduced plant diversity. Therefore, NPBTs and GMOs are vital to prevent future issues, although they should be applied alongside other solutions. The study by Kravchuk et al. (2024) examines the impact of a changing magnetic field on the density of soil composite composition, highlighting the potential effects of non-traditional factors on soil properties and plant growth. This research is particularly relevant in the context of agricultural innovation, as it delves into the

intersection of environmental conditions and soil health—key aspects of sustainable agricultural practices. The findings suggest that alterations in the magnetic field can influence soil composition, which in turn may affect crop yields. This study's focus on soil properties aligns with the research on the adoption of new technologies in Kazakhstan's agricultural sector, where soil health is a key factor in improving productivity. Like the authors, the importance of innovative practices, such as using advanced soil management techniques, to enhance soil fertility and ultimately increase agricultural yields is emphasized. While the study focuses on the application of digital technologies and precision farming, research offers a broader perspective on how environmental factors can complement these innovations for more sustainable agricultural practices. Thus, both studies underscore the need to integrate various technological and environmental factors to improve agricultural productivity (Ali et al., 2023).

Henry (2020) considered innovations in plant genetics adapting agriculture to climate change. The researcher noted that future food production will depend largely on the development of new crop varieties, including new crops and plant-based foods, and the improvement of underutilized crop species to adapt to the climate. This may include the domestication of new species and the use of wild relatives of crops to increase biodiversity. In turn, breeding for protected environments will become increasingly important as climate change progresses, especially for high-value horticultural products. Eventually, advances in functional genomics will enable plant breeders to develop optimised genotypes for specific environmental conditions, allowing much more efficient adaptation to them and hence better results in the context of yield. Considering the findings of the studies analyzed above, researchers generally come to the same conclusions that were reached in the present study. In a comprehensive review, Jat et al. (2023) discuss the role of conservation agriculture in regenerating soil health and mitigating climate change impacts, specifically in smallholder systems in South Asia. The study emphasizes the benefits of conservation agriculture practices, such as reduced tillage, residue retention, and crop rotations, for improving soil's physical properties, increasing water retention, and promoting sustainable agricultural production. This aligns with our research on Kazakhstan's agricultural innovations, where similar techniques, like precision farming and sustainable land management practices, are being implemented to address soil health and enhance productivity. The focus on climate change mitigation through agricultural practices in Jat et al. (2023) resonates with Kazakhstan's efforts to develop sustainable farming systems that can adapt to changing climatic conditions. Our findings, which highlight the integration of advanced technologies in agriculture, complement the author's work by showing that the combination of modern farming technologies and conservation practices can contribute to both environmental and economic sustainability.

The current study also addressed the significance of developing innovative technologies to achieve higher levels of food security through the better utilization of arable land. The role of agriculture in food security in developing countries has been assessed by several other researchers. Thus, Pawlak and Kołodziejczak (2020) examined considerations in the context of sustainable food production. They noted that the global socio-economic development of countries is highly uneven, resulting in food surpluses in some regions and chronic food shortages in others, especially in developing countries with low gross domestic product and poor agricultural infrastructure. The researchers concluded that poor countries typically have small arable areas per capita, a lack of innovation capacity, and economic difficulties, particularly in the area of trade balance.

Khavkhun (2024) explores the effects of mineral fertilizers on the physicochemical properties of soil in maize cultivation, highlighting the crucial role of fertilization in improving soil structure and enhancing crop yields. The study confirms that the appropriate use of fertilizers can significantly influence the soil's physical and chemical properties, thereby boosting maize productivity. This aligns closely with findings about the impact of technological advancements, such as precision farming and soil management practices, on crop yields in Kazakhstan. The research demonstrates that adopting advanced agricultural practices, including the use of targeted fertilizers and efficient resource management, can improve overall productivity. Both studies underscore the importance of improving soil management practices, whether through mineral fertilisers or precision agriculture technologies, to increase crop production efficiency while ensuring sustainability.

Dhaliwal et al. (2020) and Mok et al. (2020) studied Singapore's food security and the development of innovative technologies in the country. Researchers noted that the country imports over 90% of its food, making it vulnerable to supply chain disruptions. Although Singapore has made strides in food security, many of the technologies that could enable considerable improvements are not being implemented effectively enough. Emphasis is placed on the critical significance of scaling up urban agriculture, processing technologies, and alternative food sources, specifically by optimizing costs and finding ways to better deploy these types of technologies. Although it will probably not be possible to achieve full self-sufficiency in agriculture, it may improve the situation. In the future, Singapore should, among other things, focus on engaging with other countries and building common systems and approaches to food security (Raj et al., 2021).

Our study aligns with the findings of Poliovyi et al. (2023), who explored the role of soil cultivation methods and by-products in enhancing crop yields, particularly in the context of winter rape in Ukraine's Western Forest-Steppe. Similar to their research, our results indicate that the adoption of new technologies and agricultural practices in Kazakhstan has led to increased crop yields across various agricultural sectors. This is particularly evident in our data on the yields of major crops such as potatoes, sugar beets, and oilseeds, which have benefitted

from innovations in soil management and farming techniques. Just as Poliovyi et al. (2023) emphasize the positive impact of integrating by-products into soil management for better fertility, our findings suggest that innovation in farming practices is contributing to improved efficiency and sustainability in Kazakhstan's agriculture. Dolia & Shevchenko (2024) address the critical issue of irrigation in modern agricultural practices, particularly in the context of Ukrainian agriculture. The study provides a thorough analysis of the applicability and challenges of implementing irrigation systems under current climatic conditions and economic frameworks. The authors argue that while irrigation can significantly improve crop yield, its implementation in contemporary agriculture requires a careful balance between technological adoption, resource management, and economic feasibility. The research highlights the role of efficient irrigation systems in mitigating the risks of drought and improving the sustainability of agricultural practices. The study discusses various irrigation techniques, their cost-effectiveness, and their potential to enhance water-use efficiency, which is crucial for maintaining agricultural productivity in regions facing water scarcity.

In the current study, it was shown that the use of innovative technologies can achieve considerably better results in the context of achieving food security. Other researchers have also assessed the role of innovation in agricultural development. Thus, Ingram et al. (2020) considered the achievement of success in the context of social development using the latest technologies in the field. They noted a need to develop investments in agriculture to address a variety of socially significant problems; this process is called collaborative innovation and involves the joint identification of problems and search for solutions among farmers, researchers, and policymakers. In other words, the researchers emphasise that in the context of achieving various goals related to both social and other components of the country's development, the development of innovations, especially in agriculture, plays a vital role. Khan et al. (2021) and Jat et al. (2023) considered the role of technological innovation in the transformation of sustainable food systems. It was noted that food systems were currently facing many challenges. They arise due to population growth, competition for resources, the complexity of food chains, constant changes in climate, and several other reasons. Still, these difficulties are partly addressed by advancement in the context of innovative technology development. Thus, the cited findings support the results obtained in the present study. Nevertheless, the development of innovative technologies in Kazakhstan requires considerable support from the state. In this regard, the authorities must form a single state policy that would be aimed at the development of innovative technologies in agriculture, as well as create conditions for their development, through both the direct influence of money and the formation of conditions for their attraction.

Conclusion

The study showed that agriculture is a key sector in Kazakhstan, playing a significant role in ensuring the quality of the economy's functioning. It was concluded that Kazakhstan is actively adopting technologies in agriculture, including digital innovations, satellite monitoring, and precision farming systems, thereby increasing productivity and efficiency. Furthermore, the Republic of Kazakhstan places significant emphasis on sustainable development, particularly through the implementation of initiatives focused on soil conservation, water management, and the reduction of greenhouse gas emissions. The study concluded that to ensure quality agricultural development in the country, government support, particularly through subsidies, development schemes, credit lines, and other measures, plays an essential role. The use of such instruments helps ensure the modernisation of agriculture, increases its competitiveness and attracts investment. Analysis of the data on scientific developments in Kazakhstan showed that the country has achieved success in research and development in all sectors in general and agriculture specifically. The increase in the share of innovative products in GDP and the increase in the volume of innovative products produced showed Kazakhstan's progress in fostering the development of the innovation ecosystem. Still, diverse agricultural support approaches are needed to keep sector innovation growing at this rate. It is relevant for future research to explore other aspects of the adoption of innovative technologies in agriculture. In particular, it is important to evaluate the application of new technologies to improve water resource use and digitalization, including in SMEs, and genetically modified products.

Conflict of Interests: The authors declare that there is no conflict of interest.

Authors Contribution: All authors contributed equally in this study.

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