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INNOVATIVE DEVELOPMENT OF KAZAKHSTAN'S GRAIN SECTOR: TRENDS, CHALLENGES, AND STRATEGIC PRIORITIES

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Abstract. *The study examines and substantiates innovative solutions for the sustainable development of Kazakhstan's grain sector and identifies key areas to improve its efficiency and competitiveness amid modern economic and technological challenges. Research methodology.* The research methodology consists of general scientific and special methods that enable a comprehensive assessment of the state and development prospects of Kazakhstan's grain sector, as well as substantiate directions for implementing innovative solutions. We used systematic and structural-functional analysis to view the grain sector as a complex socio-economic system of interrelated elements. We used economic and statistical methods to analyse the dynamics of gross grain harvest, yield, and export volumes for 2020-2025, based on data from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan. The comparative method allowed us to compare Kazakhstan's innovation activity and yield with indicators from leading countries in the grain market. We used expert assessments and scenario forecasting to develop expected innovation outcomes in the short and long term - *the study's originality and value.* The originality of this study lies in an integrated approach to substantiating innovative solutions for developing Kazakhstan's grain sector, taking into account modern global challenges, including the digitalisation of agricultural production, climate change, and the transformation of global food markets - *the results of the study.* The study found that Kazakhstan's grain sector has

significant development potential. However, insufficient technological equipment, dependence on natural and climatic conditions, and uneven adoption of innovations largely limit its effectiveness. The analysis showed that the key to increasing the industry's competitiveness is digitalising agricultural production, adopting modern agricultural technologies, and developing grain storage and logistics infrastructure. The paper shows that introducing innovative solutions such as precision farming, automation of production processes, digital monitoring and management platforms, and resource-saving technologies contributes to higher yields, lower production costs, and improved product quality. Developing these areas not only increases the efficiency of domestic production but also strengthens Kazakhstan's export position in the global grain market. In addition, the study identified the significant role of government support and institutional mechanisms in stimulating industry innovation. The study shows that improved financing, subsidising, innovation mechanisms, and human resource development are necessary conditions for sustainable growth in the grain sector. The results confirm that integrated implementation of innovative solutions is a key factor in improving the efficiency, sustainability, and competitiveness of Kazakhstan's grain sector in the long term.

Keywords: grain sector, innovative solutions, digitalisation of agriculture, innovations in logistics and storage, government support

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ҚАЗАҚСТАННЫҢ АСТЫҚ СЕКТОРЫН ИННОВАЦИЯЛЫҚ ДАМУ: ҮРДІСТЕР, ПРОБЛЕМАЛАР ЖӘНЕ СТРАТЕГИЯЛЫҚ БАСЫМДЫҚТАР

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Аннотация. *Зерттеудің мақсаты* Қазақстанның астық секторын тұрақты дамытуға бағытталған инновациялық шешімдерді зерттеу және негіздеу,

сондай-ақ қазіргі заманғы экономикалық және технологиялық сын-қатерлер жағдайында оның тиімділігі мен бәсекеге қабілеттілігін арттырудың негізгі бағыттарын анықтау болып табылады. *Зерттеу әдістемесі.* Зерттеудің әдіснамалық негізін Қазақстанның астық секторының жай-күйі мен даму перспективаларын кешенді бағалауға, сондай-ақ инновациялық шешімдерді енгізу бағыттарын негіздеуге мүмкіндік беретін жалпы ғылыми және арнайы әдістер құрайды. Жүйелік және құрылымдық-функционалдық талдау астық секторын өзара байланысты элементтерден тұратын күрделі әлеуметтік-экономикалық жүйе ретінде қарастыру үшін пайдаланылды. Экономикалық-статистикалық әдіс ҚР Стратегиялық жоспарлау және реформалар агенттігінің Ұлттық Статистика Бюросының деректері негізінде 2020-2025 жылдар кезеңіндегі астықтың жалпы жиналу динамикасын, өнімділігі мен экспорт көлемін талдау үшін қолданылды. Салыстырмалы-сараптамалық әдіс Қазақстандағы инновациялық белсенділік пен өнімділік деңгейін астық нарығының көшбасшы елдерінің көрсеткіштерімен салыстыруға мүмкіндік берді. Сараптамалық бағалау және сценарийлік болжау әдісі қысқа және ұзақ мерзімді перспективада инновацияларды енгізудің күтілетін нәтижелерін әзірлеу кезінде қолданылды. *Зерттеудің өзіндік ерекшелігі/құндылығы.* Осы зерттеудің өзіндік ерекшелігі аграрлық өндірісті цифрландыруды, климаттық өзгерістерді және әлемдік азық-түлік нарықтарын трансформациялауды қоса алғанда, қазіргі заманғы жаһандық сын-тегеуріндерді ескере отырып, Қазақстанның астық секторын дамытудың инновациялық шешімдерін негіздеуге кешенді тәсілдеме болып табылады. *Зерттеу нәтижелері.* Зерттеу барысында Қазақстанның астық секторының айтарлықтай даму әлеуеті бар екені анықталды, алайда оның тиімділігі технологиялық жарактандырудың жеткіліксіз деңгейімен, табиғи-климаттық жағдайларға тәуелділікпен және инновацияларды біркелкі еңгізулуімен айтарлықтай шектеледі. Жүргізілген талдау саланың бәсекеге қабілеттілігін арттырудың негізгі факторы агроөндірісті цифрландыру, заманауи агротехнологияларды қолдану және астықты сақтау инфрақұрылымы мен логистикасын дамыту болып табылатынын көрсетті. Жұмыста дәл егіншілік, өндірістік процестерді автоматтандыру, бақылау пен басқарудың цифрлық платформаларын, сондай-ақ ресурс үнемдейтін технологияларды пайдалану сияқты инновациялық шешімдерді енгізу өнімділікті арттыруға, өндіріс шығындарын азайтуға және өнім сапасын жақсартуға ықпал ететіні негізделген. Бұл бағыттарды дамыту ішкі өндірістің тиімділігін арттырып қана қоймай, Қазақстанның әлемдік астық нарығындағы экспорттық позициясын нығайтуға мүмкіндік беретіні анықталды. Бұдан басқа, саланың инновациялық дамуын ынталандыруда мемлекеттік қолдау мен институционалдық тетіктердің елеулі рөлі анықталды. Қаржыландыру, субсидиялау және инновацияларды енгізу тетіктерін жетілдіру, сондай-ақ кадрлық әлеуетті дамыту астық секторының орнықты өсуінің қажетті шарттары болып табылатыны дәлелденді. *Зерттеу*

нәтижелері инновациялық шешімдерді кешенді енгізу ұзақ мерзімді перспективада Қазақстанның астық секторының тиімділігін, орнықтылығы мен бәсекеге қабілеттілігін арттырудың негізгі факторы болып табылатынын растайды.

Түйін сөздер: астық секторы, инновациялық шешімдер, ауыл шаруашылығын цифрландыру, логистика мен сақтаудағы инновациялар, мемлекеттік қолдау

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ИННОВАЦИОННОЕ РАЗВИТИЕ ЗЕРНОВОГО СЕКТОРА КАЗАХСТАНА: ТЕНДЕНЦИИ, ПРОБЛЕМЫ И СТРАТЕГИЧЕСКИЕ ПРИОРИТЕТЫ

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Аннотация. Цель исследования заключается в исследовании и обосновании инновационных решений, направленных на устойчивое развитие зернового сектора Казахстана, а также выявлении ключевых направлений повышения его эффективности и конкурентоспособности в условиях современных экономических и технологических вызовов. *Методология исследования.* Методологическую основу исследования составляют общенаучные и специальные методы, позволяющие комплексно оценить состояние и перспективы развития зернового сектора Казахстана, а также обосновать направления внедрения инновационных решений. Системный и структурно-функциональный анализ использовался для рассмотрения зернового сектора как сложный социально-экономической системы, состоящей из взаимосвязанных элементов. Экономико-статистический метод применялся для анализа динамики валового сбора зерна, урожайности и объемов экспорта за период 2020-2025 годы на основе данных Бюро национальной статистики Агентства по стратегическому планированию и реформам РК. Сравнительно-сопоставимый метод позволил сравнить уровень инновационной активности и урожайности в Казахстане с показателями стран-лидеров зернового рынка. Метод экспертных оценок и сценарного прогнозирования применялся при

разработке ожидаемых результатов внедрения инноваций в краткосрочной и долгосрочной перспективе. *Оригинальность/ценность исследования.* Оригинальность настоящего исследования заключается в комплексном подходе к обоснованию инновационных решений развития зернового сектора Казахстана с учетом современных глобальных вызовов, включая цифровизацию аграрного производства, климатические изменения и трансформацию мировых продовольственных рынков. *Результаты исследования.* В ходе исследования установлено, что зерновой сектор Казахстана обладает значительным потенциалом развития, однако его эффективность в значительной степени ограничивается недостаточным уровнем технологического оснащения, зависимостью от природно-климатических условий и неравномерностью внедрения инноваций. Проведенный анализ показал, что ключевым фактором повышения конкурентоспособности отрасли является цифровизация агропроизводства, применение современных агротехнологий и развитие инфраструктуры хранения и логистики зерна. В работе обосновано, что внедрение инновационных решений, таких как точное земледелие, автоматизация производственных процессов, использование цифровых платформ мониторинга и управления, а также ресурсосберегающих технологий, способствует повышению урожайности, снижению производственных затрат и улучшению качества продукции. Установлено, что развитие данных направлений позволяет не только повысить эффективность внутреннего производства, но и укрепить экспортные позиции Казахстана на мировом рынке зерна. Кроме того, выявлена значительная роль государственной поддержки и институциональных механизмов в стимулировании инновационного развития отрасли. Доказано, что совершенствование механизмов финансирования, субсидирования и внедрения инноваций, а также развитие кадрового потенциала являются необходимыми условиями устойчивого роста зернового сектора. Результаты исследования подтверждают, что комплексное внедрение инновационных решений является ключевым фактором повышения эффективности, устойчивости и конкурентоспособности зернового сектора Казахстана в долгосрочной перспективе.

Ключевые слова: зерновой сектор, инновационные решения, цифровизация сельского хозяйства, инновации в логистике и хранении, государственная поддержка

Introduction. The grain sector is a key part of the Republic of Kazakhstan's agro-industrial complex and plays a strategic role in ensuring food security and the country's export potential. Kazakhstan is one of the leading grain producers and exporters, holding significant positions in international markets, especially in wheat and flour exports. The country's geographic location and extensive arable land create the conditions for further development of grain production (Dzhumabaeva A.M. et al., 2024).

In recent years, the gross harvest of grain crops has increased, driven by both expanded sowing and the gradual adoption of modern agricultural technologies. At the same time, the industry remains highly dependent on natural and climatic factors, including droughts, soil degradation, and unstable water resources, which increases risks to the sustainable development of the grain sector.

Amid globalisation, climate change, increased competition in global food markets, and the need to improve resource efficiency, there is a growing need to modernise grain production through innovative solutions. Areas such as digitalisation of agriculture, the introduction of precision farming technologies, the development of breeding and genetic research, automation of production processes and increasing the level of deep grain processing are becoming particularly relevant (Asperov G. et al., 2023).

Another relevant factor is the need to increase the competitiveness of Kazakhstani grain on the world market, diversify export destinations, and reduce logistics costs. In this regard, studying innovative approaches to developing the grain sector has not only scientific but also practical significance, contributing to the formation of a sustainable and efficient agrarian economy.

Literature review. Domestic and foreign researchers have widely covered issues in agricultural development, particularly grain production. Works on the economics of the agro-industrial complex consider the theoretical foundations of agriculture and ways to increase its efficiency, paying special attention to innovation as a key factor in the industry's sustainable development. Modern research shows that introducing innovative technologies can significantly increase agricultural productivity and reduce dependence on natural and climatic factors (Kerimova U.K. et al., 2021a; Syzdykbaeva N.B. et al., 2021b).

Foreign authors have made a significant contribution to studying the innovative development of the agricultural sector by exploring the concept of Agriculture 4.0 and the digitalisation of agriculture. Their work examines the possibilities of using precision farming technologies, artificial intelligence, the Internet of Things (IoT), and big data analysis to improve production efficiency. The authors note that digital solutions can optimise costs, increase yields, and support the sustainability of agricultural systems amid climate change (Deniz U. et al., 2024).

In the domestic scientific literature, attention focuses on developing Kazakhstan's grain sector. Kazakh analysts' research aims to analyse the industry's current state, identify problems, and propose modernisation measures. The authors emphasise the need to introduce resource-saving technologies, improve the seed production system, and develop grain storage and processing infrastructure. At the same time, one key factor in increasing the competitiveness of the grain sector is government support and encouragement of innovation activities (Smagulova Sh.A. et al., 2023).

A separate area of research is related to the assessment of the economic efficiency of innovation in agriculture. Several authors have shown that modern agricultural technologies reduce production costs, increase yields, and improve the profitability

of agricultural enterprises. However, despite significant scientific interest in this issue, a comprehensive assessment of innovations' impact on the development of Kazakhstan's grain sector remains insufficiently studied, underscoring the need for further research in this area (Margherita Masi et al., 2022).

A review of the scientific literature shows that innovations are a key factor in the development of the grain sector; however, a deeper study of how they are implemented and how effective they are is needed, taking into account the specifics of Kazakhstan's agrarian economy.

Materials and basic methods. Kazakhstan holds an important place in the global grain market and consistently ranks among the largest exporters of agricultural products. Grain production accounts for a significant share of the agricultural structure. About 70% of arable land in the country's northern regions, such as the North Kazakhstan, Kostanay, and Akmola regions, is under grain crops. According to the USDA, in the 2024-2025 marketing year, Kazakhstan ranked 11th in the world in wheat production, with about 18.5 million tons, or about 2.3% of global production (Kaspiy Commodity Exchange JSC, 2025).

A feature of Kazakhstan's agro-industrial complex is that it exports not only raw materials but also higher-value products. In particular, according to the International Grain Council, the country is one of the world's leading flour exporters, second only to Turkey. Production volume exceeds 3.0 million tons, and exports amounted to 1.8 million tons, up 1.2% from 2024. The main sales markets are Central Asia, Afghanistan, Russia, and China (Kaspiy Commodity Exchange JSC, 2025). This indicates a more developed export structure and a shift from a raw-material orientation to a processing model.

Results. The dynamics of Kazakhstan's grain sector reveal several stable trends that reflect both the cyclical nature of agricultural production and structural shifts in the industry (Table 1).

Table 1 — Key indicators of Kazakhstan's grain sector

Indicator	Period					
	2020	2021	2022	2023	2024	2025
Grain harvest, million tons	20.1	16.4	22.0	17.0	25.2	25.9
Productivity, c/ha (centner/hectare)	12.8	10.4	13.8	10.3	15.2	16.3
Grain exports, million tons	5.2	5.7	6.3	7.2	5.9	3.8 (1st half of the year)
The share of innovative technologies, %	15.0	18.0	22.0	25.0	32.0	35.0
Note: compiled by the authors based on the source (Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, 2026. - URL: https://stat.gov.kz/ru/)						

Gross harvest dynamics are highly volatile. This instability stems from grain production's heavy dependence on natural and climatic conditions, a characteristic feature of Kazakhstan's agricultural sector. At the same time, record figures in 2025

indicate favourable weather conditions and a stronger technological base in the industry.

A similar trend has developed in terms of yield. Yield increased after the decline in the dry years of 2021 and 2023, in more favourable periods. Overall, during the analysed period, yield increased from 12.8 to 16.3 c/ha (centner per hectare; 1 c/ha = 100 kg/ha), indicating a gradual increase in production efficiency. This growth is largely due to the expansion of modern agricultural technologies, fertilisers, and improved varieties, as confirmed by an increase in the share of innovative technologies from 15% to 35%.

The dynamics of grain exports deserve special attention. Despite production fluctuations, exports show a steady upward trend, indicating a strengthening export orientation in the industry. Thus, based on the 2024-2025 marketing year results, wheat exports are estimated at 10.0 million tons, one of the highest figures in the entire history of observations and significantly exceeding the previous year's results (Kaspiy Commodity Exchange JSC, 2025).

This dynamic is largely due to high wheat yields driven by favourable agro-climatic conditions and the gradual introduction of modern agricultural technologies. The relative stability of the national currency also supports export growth by ensuring predictable pricing policy and reducing currency risk for participants in foreign economic activity. Combined with this, the competitive price of Kazakhstani grain, especially compared with key regional exporters such as Russia, helps strengthen the country's position in foreign markets.

Another factor stimulating export activity is government support, particularly subsidies for grain transportation. This tool aims to reduce logistical costs when exporting excess volumes of products from the domestic market and increase the price competitiveness of Kazakhstani grain in foreign markets.

As a result of transport subsidies, Kazakhstan significantly expanded its export geography, increasing supplies to less developed destinations such as Azerbaijan, Georgia, and Morocco, as well as to several European Union countries. This indicates greater flexibility in export policy and the gradual diversification of foreign markets.

An important structural trend is the increase in the share of innovative technologies, which has more than doubled. This indicates the industry's transition to a more intensive development model based on digitalisation, precision farming and the introduction of modern production management methods. The increase in technological efficiency directly correlates with higher yields and export potential (Lo S. et al., 2024).

Taken together, the analysis suggests that Kazakhstan's grain sector is in a stage of steady growth, with instability driven by natural factors. The key drivers of development are technological modernisation, increased export orientation, and government support for the industry.

At the same time, Kazakhstan's grain sector is facing several systemic problems

hindering its sustainable development and declining competitiveness in the global market (Figure 1):

1. High dependence on natural and climatic conditions, including droughts, precipitation fluctuations and soil degradation, which leads to yield instability
2. Significant wear and tear on agricultural machinery and infrastructure, limiting the efficiency of production processes and increasing operating costs
3. Insufficient level of digitalization of the industry, expressed in the limited introduction of precision farming technologies, automation and data management systems
4. Low degree of deep processing of grain, which reduces the added value of products and limits the export potential
5. Weak diversification of export markets, increasing dependence on certain sales areas
6. Limited access to investment resources and innovations, slowing down the technological modernization of the industry

Figure 1 — Challenges hindering the sustainable development of Kazakhstan's grain sector

Note - compiled by the authors

Given the systemic problems hindering the grain sector's development, introducing modern, innovative solutions to improve the industry's efficiency and sustainability is particularly relevant.

We will conduct a comprehensive analysis of the use of innovative technologies in the development of the grain sector in Kazakhstan in the following areas:

- I. Digitalisation of agriculture.
- II. Moisture-saving and resource-saving technologies.
- III. Development of breeding and seed production.
- IV. Innovations in logistics and grain storage.
- V. The role of government support and investments.

I. Digitalisation of the agro-industrial complex of the Republic of Kazakhstan is one of the priorities of the state policy aimed at improving the efficiency of agriculture and ensuring its sustainable development. In the period from 2018 to 2022, the digitalisation of the agricultural sector was carried out within the framework of the Digital Kazakhstan State Program based on the introduction of modern information technologies, including elements of precision farming, automation of production processes and digital platforms for agricultural business management (Government of Kazakhstan, Decree No. 827 of December 12, 2017, 2017).

By 2025, the digitalisation of Kazakhstan's agro-industrial complex has transformed into a systematic industry management tool that ensures transparency

of business processes and effective control of the entire production and distribution chain - from the stage of agricultural production to its sale and export.

Discussion. As part of the digital transformation, an updated Roadmap for developing the agro-industrial complex until 2027 was approved, providing for the digitalisation of 144 key business processes. Special attention is given to reengineering agrochemical soil survey procedures and government support mechanisms. These measures aim to automate processes, integrate information systems, and improve the reliability and quality of the data used. The development and improvement of industry information systems such as GISS, ILI, EASA and E-Fish, which cover key areas of agricultural activity, including subsidies, land management and crop production, continues. A key area is the introduction of mobile digital services that simplify agricultural producers' access to public services and increase efficiency (Akhmetova L. et al., 2026).

One of the most significant projects was the system of traceability in crop production, covering the full production cycle - from the use of seed material to the sale of finished products. The pilot testing of the system was successfully carried out in the Akmola region, and national scaling is planned from 2026. Integration with satellite monitoring technologies enables accurate acreage recording, which helps increase industry transparency and minimise the risk of unjustified subsidies.

Leading in digitalisation are regions such as Akmola, North Kazakhstan, Pavlodar, Kostanay, and Zhetisu. These regions are actively implementing innovative solutions, including algorithms to predict pest spread and digital support services for farmers, such as the Subsidisation chatbot (Ministry of Agriculture of the Republic of Kazakhstan, 2026).

Digitalisation is gaining particular importance in the grain sector, which is a key element of the country's agriculture. In recent years, precision farming technologies have been introduced, including GPS navigation, equipment monitoring systems, remote sensing of the Earth, and agro-climatic platforms. This allows agricultural producers to manage the application of fertilisers and plant protection products more efficiently and reduce production costs (Zhumaxanova K.M. et al., 2019).

However, the level of digital technology penetration in the grain industry remains limited. According to experts, the share of farms using precision farming elements does not exceed 25-30%, while digital solutions are fully used in only 10-15% of enterprises. This indicates that there is significant potential for further digital transformation of the industry.

The limiting factors of digitalisation are:

- insufficient development of digital infrastructure in rural areas;
- high cost of introducing innovative technologies;
- shortage of qualified personnel in the field of agroeconomics;
- low level of digital literacy among agricultural producers;
- limited access to financing for innovative projects.

At the same time, the digitalisation of agriculture and the grain sector provides

significant economic benefits. Digital technologies can reduce production costs by 15-20%, increase yields by 20-30%, and improve the overall profitability of agricultural production. In addition, digital solutions increase transparency in the agricultural business, improve management quality, and strengthen the industry's export potential.

II. In the conditions of Kazakhstan's arid climate, moisture-saving and resource-saving technologies are of particular importance, since agriculture is the largest consumer of water resources. According to government agencies, the agricultural sector accounts for about 60% of the country's total water consumption, making efficient water use a key factor in sustainable industrial development.

Kazakhstan's agro-industrial complex is currently characterised by the adoption of innovative methods to preserve soil moisture and improve resource-use efficiency. The most common technologies include No-Till and Mini-Till systems, which minimise tillage and preserve natural moisture, as well as drip and sprinkler irrigation, which ensure targeted and economical water use (Zhapaev R.K. et al., 2024).

The state plays a significant role in stimulating the introduction of these technologies. In 2024, subsidies for farmers using moisture-saving solutions increased from 50% to 80%, accelerating the transition to modern irrigation systems and infrastructure modernisation. In addition, large-scale projects are being implemented to build reservoirs and reconstruct irrigation networks to increase water availability in rural areas.

The country's climate makes introducing moisture-saving technologies even more urgent. In some regions, such as the west, precipitation is about 300 mm per year. At the same time, evaporation exceeds this figure by 3-4 times, creating a moisture deficit and requiring special agricultural technologies. In these conditions, farmers use methods such as row-by-row “dry” irrigation (applying water directly to plant rows rather than the whole field), mulching, and optimising crop structure.

Despite these benefits, developing water-saving technologies faces several challenges. The main ones include:

- the high cost of implementing modern systems;
- insufficient level of technical equipment of individual farms;
- Persistent regional inequalities in access to water resources and infrastructure.

At the same time, experts note the potential for expanding the use of these technologies to 1 million hectares of agricultural land in the coming years.

III. The development of seed breeding in the Republic of Kazakhstan is a strategically significant area of agricultural policy, directly related to ensuring food security, increasing yields and reducing import dependence. The industry is currently characterised by significant scientific potential alongside systemic problems that hinder its effective development.

On the one hand, Kazakhstan has established a scientific and production base in breeding and seed production. Research institutes, experimental stations, and

specialised farms select grain, oilseed, and fodder crops and develop new varieties with higher yields and adaptability to various soil and climatic conditions. As part of scientific and technical programs, for example, for 2024-2026, projects are being implemented to breed competitive varieties with improved productivity and stress resistance. In addition, the state has approved a Comprehensive plan for the development of breeding and seed production for 2024-2028, aimed at systemic reform of the industry. (Government of Kazakhstan, Decree No. 427 of May 30, 2024, 2024).

On the other hand, the industry is facing several serious challenges. According to experts, seed production remains one of the most vulnerable sectors of crop production in the country. Among the key limitations are:

- insufficient level of introduction of modern biotechnology;
- weak material and technical base of several farms;
- shortage of qualified personnel;
- insufficient integration of science with production.

The sector also relies heavily on imported seeds for individual crops, reducing its resilience to external risks. Total market demand is estimated at 2.5 million tons of seeds, while domestic production does not always fully meet this demand. Another problem is an imperfect institutional environment, including the protection of intellectual property for breeding achievements and the promotion of private investment in the industry. This limits the commercialisation of scientific developments and slows the renewal of crop varietal composition.

At the same time, positive trends are emerging. Government support for agricultural science is increasing, funding for scientific programs is rising, digitalisation and precision farming are being introduced, and work on conserving and using plant genetic resources is expanding. Practice shows that using high-reproduction seeds can increase yields by 10-15%, confirming the strong economic efficiency of seed production development.

Breeding and seed production in Kazakhstan is undergoing structural transformation: despite strong scientific potential and government support, systemic constraints remain and require a comprehensive solution.

IV. The current state of grain logistics and storage in Kazakhstan is characterised by a combination of significant infrastructural potential and continuing structural constraints, which determines the need for active implementation of innovative solutions.

First, Kazakhstan has a well-developed grain storage system. As of 2025, the total capacity of grain storage facilities is about 30.7-30.9 million tons, of which 13.3-13.5 million tons are held in licensed elevators and 17.4 million tons in storage facilities owned by agricultural producers. The country has about 207 licensed grain elevators, which form the basis of the storage infrastructure. At the same time, load levels vary; for example, in some periods they are 17-42%, indicating reserve capacity of 7-11 million tons of free volume. This makes it possible to receive even record harvests exceeding 25 million tons.

However, quantitative infrastructure indicators do not always match qualitative compliance with modern requirements, necessitating technological modernisation. Many elevators were built during the Soviet period and are characterised by heavy wear, limited automation, and low energy efficiency. In addition, capacities are concentrated in the northern grain-growing regions (Akmola, Kostanay, North Kazakhstan regions), creating logistical imbalances and increasing transport costs.

The development of transport and logistics infrastructure is also essential. Kazakhstan, having transit potential between the markets of Europe and Asia, is actively developing multimodal routes, including railway corridors and dry ports. In 2025, shipments through the national carrier's network exceeded 14.3 million tons, up 31% from the previous year (APK-Inform Asia, 2025). This indicates increased export flows and a greater burden on transport infrastructure. Additionally, grain supplies to grain elevators increased to 7.7 million tons at the beginning of the 2025 season, more than twice the level in the same period last year.

At the same time, the key problems of the logistics system remain.:

- limited capacity of the railway infrastructure during peak periods;
- dependence on transit routes, including exports through neighbouring countries;
- insufficient level of digitalisation of supply chains. In some cases, this leads to delays in shipments and increased logistical costs.

Overall, Kazakhstan's grain logistics and storage are infrastructurally sound but technologically heterogeneous. Significant storage capacity and growing transportation volumes create a solid foundation for industry development; however, further improvement and modernisation require facility upgrades, digitalisation of logistics processes, and the elimination of regional imbalances.

V. The development of state support and investment support for the grain sector of the Republic of Kazakhstan is characterised by a significant strengthening of financial instruments, the expansion of subsidy mechanisms and the growing role of the state as a key driver of technological modernisation of the industry.

First, agricultural financing has grown at an unprecedented rate. In 2024, the volume of preferential agricultural financing reached 580 billion tenge, a record figure in recent years. The funds were used for direct lending to farmers, subsidising interest rates, and forward purchases of agricultural products, enabling farmers to access working capital at all stages of the production cycle. Moreover, in 2025, financing increased to 700 billion tenge, and total state support for agriculture is estimated at 1.3-1.4 trillion tenge, indicating the industry's strategic priority.

The analysis shows that increased government support directly affects grain production results. Thus, with expanded financing and resource availability, Kazakhstan achieved a record grain harvest of about 25.9 million tons with a yield of 16.3 c/ha, significantly higher than in previous years (Ministry of Agriculture of the Republic of Kazakhstan, 2024). This confirms the effectiveness of support measures that provide farmers with high-quality seeds, fertilisers, plant protection products, and modern technology.

An important element of government policy is the development of investment support tools. Mechanisms for preferential leasing of agricultural machinery have been introduced, for example, programs worth 120 billion tenge at 5% per annum, subsidising up to 30% of the cost of domestic machinery, as well as guaranteeing loans through state development institutions, which reduces agribusiness financial risks. These measures help accelerate the renovation of the material and technical base, which increased from 1.9% in 2017 to 4.5% in 2023. However, it remains below the regulatory level of 8-10% (Ministry of Agriculture of the Republic of Kazakhstan, 2024).

The improvement of financial resource allocation mechanisms also plays a significant role. In recent years, the number of financing channels has been expanded to six, loan guarantee tools have been introduced for up to 85% of the loan amount, and earlier availability of credit facilities has been ensured - even before the start of the seed company. This increases the financial stability of agricultural producers and allows them to plan production processes more efficiently.

Despite the positive trends, certain limitations remain among them:

- dependence of investment efficiency on natural and climatic conditions;
- uneven distribution of financial resources between regions and categories of farms;
- insufficient involvement of private capital in innovative projects;
- the problem of insufficient payback in certain areas, which requires further improvement of government support mechanisms.

The current state of government support and investment in the country's grain sector reflects a phase of increasing financial resources and institutional development. The state acts as a key investor and regulator in the industry, supporting growth in production indicators and technological modernisation. In the future, the effectiveness of these measures will depend on their focus on innovation, sustainable production, and private investment.

Based on a comprehensive analysis of the application of innovative solutions in developing Kazakhstan's grain sector, we will assess the impact of innovations on efficiency (Table 2).

Table 2 — Comparison of traditional and innovative production

Indicator	Unit of measurement	Traditional technologies	Innovative technologies
Productivity	c/ha (centner/ha)	10-12	14-18
Costs per 1 ha	thousand tenge	80	95
Profit per 1 ha	thousand tenge	30	70
Profitability	%	37.5%	73.7%
Note: compiled by the authors based on sources (https://stat.gov.kz/ru), (https://ccx.kz/wp-content/uploads/2025/09/23)			

The key result of introducing innovative technologies is a significant increase in yields, averaging 30-50%. This increase aligns with scientific and practical estimates, which suggest that introducing precision farming technologies, digital

monitoring systems, and modern agricultural technologies can increase yields by 25-30%. This indicates the transition from an extensive production model to an intensive one based on more efficient use of resources.

At the same time, costs per hectare increase from 80 to 95 thousand tenge (about 18-20%). This cost increase is due to investments in modern technologies: GPS navigation, sensors, digital platforms, and high-quality seeds and fertilisers. However, this growth is investment-driven and is offset by a significant increase in production profitability. Moreover, innovative optimisations make it possible to optimise the use of resources, for example, to reduce fertiliser consumption by up to 30-50% and fuel by 15-25%, which in the long term reduces the cost of production.

The most significant is the increase in profit per 1 hectare, which has more than doubled. This reflects the synergistic effect of increasing yields and optimising production processes. In real-world conditions in Kazakhstan's agricultural enterprises, introducing digital solutions already enables significant savings. As a result, profitability has increased by almost twofold. This key indicator shows that innovative technologies not only increase production performance but also significantly improve the financial performance of agricultural enterprises. High profitability increases the industry's investment attractiveness and stimulates further innovation.

The analysis showed that traditional technologies have lower costs but are significantly less efficient and profitable. Innovative technologies, despite higher initial investments, provide multiple increases in productivity and financial returns (Figure 2). This confirms that the strategic development of Kazakhstan's grain sector should focus on digitalisation, technology innovation, and modernisation to increase the industry's sustainability and competitiveness in the global market.

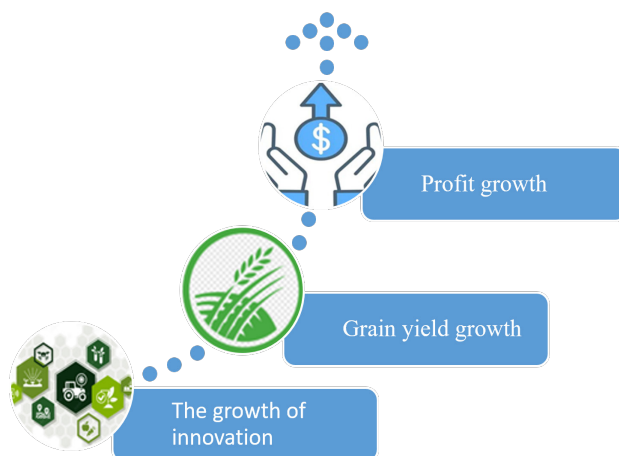


Figure 2 — The impact of innovative technologies on the economic results of agricultural production

Note - compiled by the authors

Based on an analysis of the current state of the grain sector in the Republic of Kazakhstan, including an assessment of production indicators, technological development, logistics infrastructure, and government support mechanisms, it is possible to identify key areas for innovation in the industry. Implementing these measures aims to increase the efficiency of agricultural production, strengthen export potential, and ensure the sustainability of the agricultural system in the face of global challenges such as climate change, increasing competition in world markets, and the need for technological modernisation. In this context, the following priority areas are of particular importance (Figure 3).

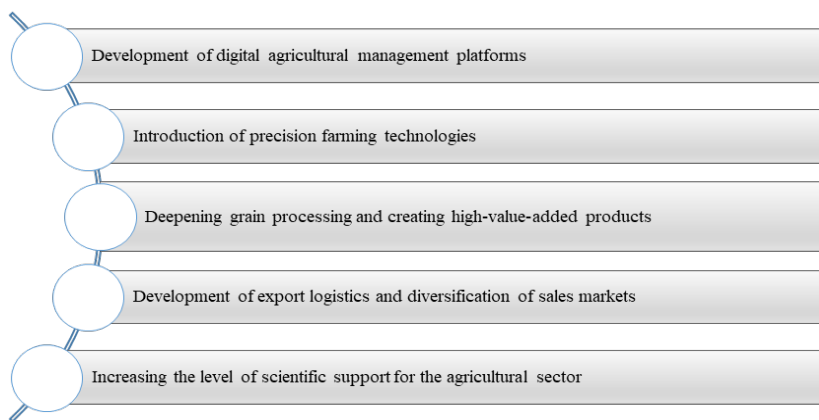


Figure 3 — Priority directions of innovative development

Note - compiled by the authors

A key area of modernisation is the transition to Agriculture 4.0, based on the widespread use of digital technologies. The prospects for digitalisation of the grain sector in Kazakhstan are associated with the development of the AgroTech ecosystem, the introduction of platform solutions, the use of artificial intelligence and the expansion of government support for innovative projects (Deniz U. et al., 2024a; Ministry of Agriculture of the Republic of Kazakhstan, 2025b). Table 3 presents the main AgroTech directions for the domestic market.

Table 3 — AgroTech directions for the domestic market

Direction	Technologies	Effect
Precision farming	GPS navigation, field maps, differentiated input	Yield growth by 25-35%
Iot monitoring	Sensors for humidity, temperature, and soil conditions	Reduction of water consumption by about 20%
Drones	Aerial photography, NDVI monitoring, spraying	Reduction of pesticides by 25-30%
AI analytics	Forecast of yields, diseases, optimal timing	The accuracy of forecasts is 10-15%

ERP for the agro-industrial complex	Accounting, logistics, finance, document management	Reducing reporting time by up to 40%
Marketplaces	Online product sales, direct contracts	Increase in value up to 10-15% of the sale price
Note - compiled by the authors based on the sources (Deniz U. et al.,2024a), (Mimansha Raj et al.,2025b), (Avola G. et al.,2024c), (George Mgendi, 2024d), (Albino Martinez Sibaja et al.,2025e)		

Precision farming is a key foundation of AgroTech. It involves a differentiated approach to agricultural land management, in which each area of the field receives the optimal number of resources depending on its characteristics. High-precision GPS navigation minimises overlap and increases machinery efficiency; analysis enables assessment of individual field productivity. Differentiated fertilisation reduces costs and increases yields. Additionally, satellite imagery and NDVI analysis monitor crop conditions, while sensors, drones, and agroanalytical platforms work together to increase profitability, reduce environmental burden, and support sustainable agricultural development. (George Mgendi, 2024a) (Albino Martinez Sibaja et al., 2025b).

Despite these limitations, the potential for introducing digital technologies remains significant and requires government policy support and investment in industry innovation.

Deepening grain processing and creating high-value-added products is a strategically important direction for developing the grain sector of the Republic of Kazakhstan, ensuring the transition from a raw-material orientation to an industrial and innovative model. In this regard, it is necessary to stimulate the development and modernisation of deep processing enterprises, for example, the production of starch, gluten, animal feed, etc., expand the export of processed products, as well as introduce modern biotechnology and innovative solutions. It is essential to strengthen government support through concessional financing, tax preferences, and subsidised investments, as well as by forming agro-industrial clusters that ensure integration of the chain «from raw materials to finished products». Implementing these measures will increase the added value, competitiveness, and sustainability of the grain sector in domestic and foreign markets. (Mimansha Raj et al.,2025).

The development of export logistics and the diversification of sales markets should be considered the most important innovative component of the country's grain sector, ensuring increased efficiency and sustainability of foreign economic activity. In modern conditions, the introduction of innovative solutions, such as:

- digital logistics management platforms (monitoring systems for loading elevators and grain movement);
- automated storage quality control systems (temperature and humidity);
- development of multimodal logistics and export hubs;

- modernisation of elevators with the introduction of energy-efficient technologies;
- integration of logistics infrastructure into international transport corridors.

At the same time, sales diversification should be based on digital trading platforms, marketing analytics, and demand-forecasting tools to expand export geography and reduce dependence on traditional destinations.

Increasing scientific support for the agricultural sector should be a key innovative component of developing grain production in Kazakhstan, ensuring the transition to a scientifically sound and technologically sustainable management model. In this context, integrating science, education, and production; developing applied research; and introducing modern advances in agricultural science are particularly important. It is necessary to strengthen funding for research programs, expand the network of experimental farms and demonstration sites, and provide technology and knowledge transfer directly to agricultural producers. An important area is the training and advanced training of personnel capable of effectively applying innovations in practice. Implementing these measures will increase the productivity, adaptability, and sustainability of the agricultural sector, as well as accelerate the introduction of innovations in grain production (Albino Martinez Sibaja et al., 2025).

To effectively implement the proposed directions for innovative development of the grain sector in Kazakhstan, the government must support and develop investments in a systemic, long-term manner focused on increasing the industry's competitiveness and sustainability. In this regard, it seems advisable not only to preserve, but also to optimise the volume of concessional financing, favouring investment projects with high added value. At the same time, it is necessary to improve subsidy mechanisms by switching to a more targeted, results-oriented model that considers farm efficiency indicators, technology levels, and contribution to export potential.

It is essential to step up private investment attraction by expanding public-private partnership instruments, introducing co-financing mechanisms, and developing guarantee institutions that reduce credit risks for investors. Another key area is creating a favourable investment environment by simplifying administrative procedures, increasing transparency in the distribution of government support, and developing digital platforms for government-business interaction.

Implementing these measures will not only increase the grain sector's investment attractiveness but also support its transition to an innovative growth model that can adapt effectively to external and internal challenges.

Conclusion. The grain sector of the Republic of Kazakhstan is not only the foundation of food security, but also a critical driver of macroeconomic stability. However, maintaining the current export- and raw-materials model risks long-term technological lag. Transforming the industry through the integration of digital technologies, agricultural science, and deep processing is not just a tool

for increasing efficiency, but an alternative way to ensure the country's global competitiveness.

The synergy of government support and private investment in infrastructure modernisation will make it possible to transform Kazakhstan's grain belt into a high-tech agricultural cluster. The implementation of this strategy involves obtaining the following measurable results.

Expected results of the implementation of innovative strategies in the short-term operational efficiency stage:

- cost reduction by optimising the cost of fuels, fertilisers, and seed stock by 15-20% through the introduction of precision farming technologies and satellite monitoring systems;
- an increase in the average grain yield by 10-12% in arid regions due to the scientifically based selection of adaptive varieties and the introduction of moisture-saving technologies;
- digital transparency based on the formation of a unified national database of soil quality and agroecological monitoring, which will automate the processes of subsidy allocation and state regulation by 100%.

In the long term, the following results are expected from the implementation of innovative solutions as a stage of structural leadership:

- export diversification based on the transition from the dominance of raw grain in exports to an increase in the share of deep-processed products to 25-30% of total production;
- economic sustainability by reducing the dependence of industry revenues on the volatility of world wheat prices by creating high-value-added products whose market price is more stable than the raw material price;
- global positioning by consolidating Kazakhstan in the top 5 global exporters of not only wheat, but also innovative feed additives and environmentally friendly food products;
- the environmental effect is to reduce the carbon footprint of grain production by 15% due to the introduction of resource-saving technologies and principles of a «green» economy in the agricultural sector.

Thus, innovative development of the grain sector will provide a multiplier effect for Kazakhstan's entire economy; successes in digitalisation will create the necessary financial groundwork for deep industrial transformation, which, in the long term, will shift agriculture from a subsidised industry into a powerful source of high-tech non-primary exports.

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