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Problems and prospects of food security in the agro-industrial complex of Kyrgyzstan: Economic analysis and recommendations

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► **Abstract.** The study focused on analysing the state of the agro-industrial complex of the Kyrgyz Republic to develop measures for its modernisation in the context of ensuring food security. An analytical approach was used, which included a systematic analysis of statistical data on agriculture, animal husbandry, and the food industry. The main focus was on investigating the dynamics of agricultural production, including the growth of livestock and crop production, and analysing current trends in food processing and production. The study identified the main challenges affecting food security: climate change, price instability in global markets, dependence on imports, and insufficient infrastructure. Challenges in product processing, storage, and farmer financing were identified alongside encouraging growth in food production, emphasising the need to strengthen the national agro-industrial sector. The analysis revealed opportunities for agricultural diversification, technological innovation, and more efficient use of water and land resources through cooperative development. Key priorities include establishing regional logistics hubs, upgrading storage and processing facilities, and expanding government support programmes to create a more resilient agricultural system. The need for coordination with international organisations such as the United Nations and the World Bank to implement sustainable development strategies, including the sustainable development goals, was highlighted. The paper included an exhaustive examination of the present circumstances and pragmatic

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suggestions intended to enhance Kyrgyzstan's food security amid global difficulties. The results obtained can be used by government agencies, agricultural enterprises, and farmers to develop strategies for the development of agriculture, increase its sustainability, and ensure the country's food independence

▸ **Keywords:** agriculture; sustainable development; resource management; technological modernisation; public policy

▸ Introduction

Food security represents a critical challenge for Kyrgyzstan due to the country's heavy reliance on food imports and limited domestic agricultural capacity. The nation's vulnerability stems from its dependence on external suppliers, constrained resources, and exposure to global disruptions, including climate variability and geopolitical tensions that can disrupt supply chains and affect food availability. Agriculture forms the backbone of Kyrgyzstan's economy, yet the sector struggles with significant structural weaknesses. Low agricultural productivity, inadequate mechanisation, and restricted access to modern farming technologies limit the country's ability to achieve food self-sufficiency. These challenges are compounded by volatile global commodity prices that create uncertainty for both producers and consumers, making food affordability and access unpredictable. The complexity of food security extends beyond simple availability to encompass accessibility, stability, and nutritional quality of food supplies. Environmental considerations including soil quality, water resources, and climate patterns further influence the agricultural system's capacity to meet population needs. The country needs strategic planning that considers both immediate food security concerns and long-term sustainability goals. This includes investing in agricultural modernisation, developing resilient supply chains, and creating policies that support both producers and consumers while building the foundation for a more self-reliant food system.

A multitude of studies exist on food security and the agro-industrial complex, enhancing comprehension of the challenges and opportunities within this critical domain. Thus, Z.A. Musarova & C.U. Adamkulova (2023) emphasised the importance of developing local production and the transition to more sustainable agricultural technologies, which is particularly relevant for countries with vulnerable agricultural sectors. In turn, the study by N. Khan *et al.* (2021) contended that addressing the food crisis necessitates the establishment of a governmental programme to subsidise and train local producers, hence enhancing agricultural yields and sustainability.

S.K. Patel *et al.* (2020) stressed that in order to ensure food security, it is important not only to develop the agricultural sector, but also to improve infrastructure, which is a key factor in ensuring equal access to food for all segments of the population. V. Kozhogulova *et al.* (2023) revealed the most important problems in the field of state regulation of agriculture in Kyrgyzstan, where significant government investments in the agro-industrial complex often do not lead to expected results due to insufficient coordination between government agencies and the lack of a long-term strategy.

L. Hao *et al.* (2022) emphasised the important role of foreign trade and international economic relations in ensuring food security, pointing out that the opening of new markets and the improvement of trade relations can become a significant tool for solving food security problems. G.S. Malhi *et al.* (2021) examined the impact of climate change on agricultural production and focused on the fact that agro-climatic conditions require adaptation to new challenges such as droughts and sudden temperature changes, which seriously affect agricultural sustainability and food security.

S.S. Hasan *et al.* (2020) identified the problem of inefficient use of agricultural land. They found that many farmers do not use the land at full capacity, which reduces the overall contribution of agriculture to the country's economy and leads to the irrational use of land resources. S.R. Semenov & N.S. Semenov (2024) showed that agrarian reforms in Kyrgyzstan, although they brought some improvements, still did not solve the problems of food security sustainability in the long term. They suggested developing risk management systems and investing in research aimed at identifying new ways to overcome agricultural problems.

H. Feng *et al.* (2020) highlighted the need to improve food chains, pointing out that many food security issues relate not only to production, but also to logistics and product distribution, which requires significant efforts to improve infrastructure and logistics in the agro-industrial sector. Ultimately, the study by C. Ene (2020) examined food security issues from the perspective of international trade. The researcher suggested that countries can significantly improve their food security by concluding strategic trade agreements with neighbouring countries, which reduces dependence on external factors and increases the stability of food supplies.

Notwithstanding extensive research on food security, certain aspects within the agro-industrial complex necessitate additional investigation. Inadequate attention has been paid to the methods of governmental support for the agriculture sector to enhance food security. Insufficient emphasis has been directed towards the sustainable management of land and water resources, considering their constraints and evolving climate circumstances. The problem of adaptation of farms to economic challenges, such as price fluctuations and technological lag, also remains poorly investigated.

The study aimed to formulate recommendations for enhancing the sustainability of food security within Kyrgyzstan's agro-industrial complex. The study intended to analyse the current status of food security in Kyrgyzstan, evaluate the efficacy of existing governmental support programmes for the agro-industrial sector, and assess their impact on food sustainability.

▸ Materials and methods

The primary emphasis was on analysing the condition of the agro-industrial complex of the Kyrgyz Republic, its influence on national food security, and evaluating the

principal reasons constraining the industry's development. The study used a systematic analysis of statistical data provided by the National Statistical Committee of the Kyrgyz Republic (n.d.). The main sources of information were data for 2020-2024, including agricultural production volumes, food industry indicators, and macroeconomic indicators. These data helped to determine the dynamics of production and identify key trends and changes in the agro-industrial sector. Particular emphasis was placed on the examination of categories including the production of meat, milk, eggs, grains, vegetables, fruits, and industrial crops.

To evaluate food security in Kyrgyzstan, researchers created visual representations through charts and data displays to track agricultural changes and pinpoint regions most at risk. The study examined key indicators such as the share of agriculture in Kyrgyzstan's gross domestic product (GDP), livestock and crop production, and food production. The study also examined Kyrgyzstan's international agricultural trade patterns, measuring both incoming and outgoing product flows to understand the country's reliance on foreign food sources and identify opportunities for increased exports. Researchers further investigated how well citizens' incomes could support their food purchases, providing insights into food accessibility and how price fluctuations affect what people can afford to buy.

When analysing the data, special attention was paid to external and internal factors affecting food security. Climate changes, including their impact on crop yields, and infrastructural constraints such as the lack of up-to-date storage and processing systems were considered. These variables were analysed regarding the availability and stability of food supply, a crucial element of comprehensive food security. The study performed a comparative analysis of Kyrgyzstan's agro-industrial complex alongside sophisticated and comparable nations, including the Netherlands, Israel, the USA, Japan, and Uzbekistan.

To develop the recommendations, a forward-looking analysis was used, considering national development strategies such as the National Development Programme of the Kyrgyz Republic until 2026 (2021), and global benchmarks presented by Sustainable Development Goals (n.d.). The study advocated strategies to implement advanced technology, including precision agriculture, soil monitoring systems, and efficient water resource management. The efficacy of these strategies was assessed for their influence on the sustainable growth of agriculture and the national food system. The Programme for the Development of Agricultural Cooperation in the Kyrgyz Republic for 2023-2027 (Resolution of the Cabinet of Ministers of the Kyrgyz Republic No. 41, 2023) was examined, focusing on bolstering farmers' groups, enhancing their competitiveness, and incorporating small producers into agro-industrial chains.

An important element of the methodology was the assessment of the role of government support and international cooperation. Measures aimed at improving the financing of farmers, developing cooperatives and stimulating the processing of agricultural products were investigated. In addition, the study considered the possibilities of agricultural diversification, such as the cultivation of export-oriented crops, which will increase the competitiveness of the Kyrgyz Republic in international markets.

▸ Results

Food security represents a cornerstone of state stability and sustainable development, encompassing economic, social, environmental, and political dimensions that determine a nation's capacity to ensure adequate, high-quality, and affordable food for its entire population. As globalisation, climate change, and economic crises intensify, food security has evolved from a domestic policy concern into a critical international security issue (Vågsholm *et al.*, 2020). At its core, food security requires states to guarantee sufficient food products that satisfy both quantitative and qualitative population needs while maintaining resilient food supply chains that prevent food crises. This multifaceted challenge demands comprehensive approaches that address production capabilities, distribution networks, economic accessibility, and nutritional adequacy. The interconnected nature of modern food systems means that disruptions in one area can cascade across entire regions, making food security a shared responsibility that transcends national boundaries. Food security encompasses four key components: accessibility, affordability within purchasing power, supply stability, and food quality (O'Hara & Toussaint, 2021).

Food availability refers to the enough quantity of items produced domestically or imported to satisfy the population's demands. In developing economies like Kyrgyzstan, food availability is intricately connected to the agriculture sector, which predominantly serves as the primary source of food supply. However, the situation may be complicated by low productivity, high import costs, and unstable harvests. Accessibility within the limits of purchasing power encompasses the economic aspect of food security. The problem is that even with enough food, not every citizen can afford the necessary amount of food due to low incomes or inequality in the distribution of wealth (Pokhrel, 2020).

The stability of food supplies means the ability to maintain uninterrupted food supplies over a long period of time, regardless of seasonal fluctuations, natural disasters, or external economic shocks (Davis *et al.*, 2021). This is an important aspect for countries with limited natural resources, such as Kyrgyzstan, where the role of foreign trade and imports is invaluable. The quality of nutrition consists in providing the population not only with the quantity of products, but also with their diversity, nutritional value, safety, and compliance with relevant health requirements. It is important that food not only meets energy needs, but also provides the body with all the necessary vitamins, minerals, and trace elements. Food security is a complex notion that includes both the production and the economic accessibility and stability of the food supply. In the face of global challenges and internal instability, states must not only solve production problems, but also build effective distribution systems, resource management, and sustainable agricultural development. For Kyrgyzstan, with its dependence on external supplies and vulnerability to natural risks, food security is becoming the foundation of social well-being and economic stability.

The agro-industrial complex serves as the cornerstone of global food security by managing the production and processing of agricultural products. Its operational

efficiency determines food availability, economic stability, and population welfare across nations. Contemporary challenges including climate change, demographic expansion, and geopolitical tensions have amplified the sector's economic significance (Viana *et al.*, 2022). Advanced economies demonstrate this principle effectively. The United States, Germany, France, and Japan operate sophisticated agro-industrial systems characterised by extensive mechanisation, cutting-edge technologies, and intensive cultivation practices. Conversely, developing nations encounter substantial obstacles in agricultural development. Countries such as India, Pakistan, Kenya, and Uzbekistan struggle with productivity limitations, restricted technological access, and heavy reliance on imported food and agricultural inputs. Traditional farming methods predominate in these regions, where manual labor and basic mechanisation constrain production capacity and economic growth (Da Silveira *et al.*, 2021).

Stable food production reduces dependence on imports, reducing vulnerability to external shocks such as price fluctuations in global markets or trade restrictions. In addition, an efficient agro-industrial complex can become an export driver, providing an influx of foreign exchange and contributing to economic growth (Garcia *et al.*, 2020). The use of digital farm management systems, biotechnologies and precision farming methods can significantly increase yields and reduce the environmental burden. Droughts, floods, and other natural disasters require technology adaptation and the transition to sustainable farming practices (Shang *et al.*, 2021). In addition to its industrial and economic role, the agro-industrial complex performs an important social function, providing employment and income for a significant part of the population, especially in rural areas. The sustainable development of agricultural production contributes to reducing poverty, improving living standards and improving the social climate. The generation of employment in the agricultural sector is crucial for mitigating migration from rural areas to urban centres and abroad, hence preserving population distribution equilibrium (Laurett *et al.*, 2021).

The efficient operation of the agro-industrial complex is unattainable without a meticulously formulated government strategy. This includes farm subsidies, support for innovative technologies, infrastructure development, and easier access to credit resources. National and international level programmes such as Sustainable Development Goals (n.d.) emphasise the need to modernise the agricultural sector and introduce sustainable production methods to ensure global food security. The agro-industrial complex has significant potential for sustainable development. Improving the efficiency of resource management, improving logistics and developing processing capacities can not only increase production volumes, but also reduce losses at all stages of the food chain. The variety and quality of products also play an important role, as compliance with international standards opens up opportunities for integration into global markets.

The agro-industrial complex of Kyrgyzstan constitutes a vital sector of the economy, contributing substantially to GDP and serving as the primary source of employment for over 60% of the rural populace (National Statistical Committee of the Kyrgyz Republic, n.d.). Agriculture, traditionally the backbone of the country's food system, faces a number of structural problems, such as low levels of mechanisation, insufficient use of innovative technologies, limited access to financial resources, and inefficient infrastructure. The agro-industrial complex mostly comprises small and medium-sized farms that generate the majority of agricultural goods; nevertheless, their operations are frequently constrained by inadequate productivity and antiquated farming techniques.

An increase in domestic production helps to reduce dependence on imports, which makes the country less vulnerable to external economic shocks, such as fluctuations in world prices for agricultural products and logistical problems. In addition, improved productivity helps to improve the quality of food products, providing the population with a more stable and affordable food supply. To achieve sustainable growth, it is necessary to solve existing problems, such as upgrading agricultural technologies and improving the infrastructure for storing and processing products (Fig. 1).

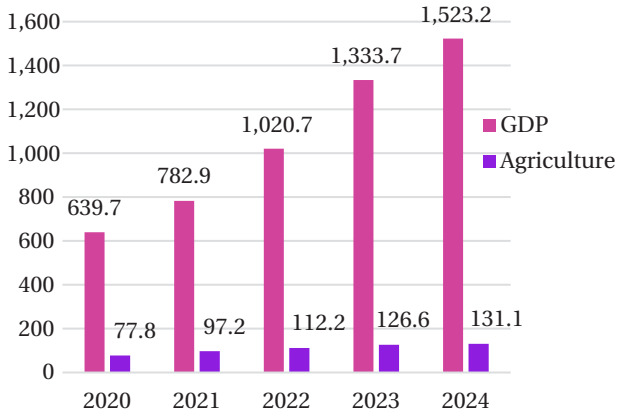

Figure 1. Share of agriculture in Kyrgyzstan's GDP for 2020-2024, billion KGS

Source: developed by the authors based on data from the National Statistical Committee of the Kyrgyz Republic (n.d.)

Agriculture continues to be a significant sector of the Kyrgyz economy; however, its proportion in the GDP composition is declining. Despite the increase in absolute agricultural production from KGS 77.8 billion in 2020 to KGS 131.1 billion in 2024, the country's total GDP is growing at a faster pace. This signifies structural transformations in the economy, wherein the significance of alternative sectors, such as industry and services, is increasing. Nonetheless, the steady advancement of the agro-industrial complex is essential for food security and economic stability, particularly given the significant employment of the rural populace in this sector.

The most common industries are crop production (production of wheat, corn, potatoes, vegetables, and fruits) and animal husbandry (breeding of cattle, sheep, and goats). Despite the variety of agricultural products, most farmers are self-sufficient, which limits their participation in the market economy and makes it difficult to develop processing capacities. Table 1 shows the volume of livestock production for all categories of farms.

Table 1. Livestock production in Kyrgyzstan for 2020-2024

Year	2020	2021	2022	2023	2024
Cattle and poultry for slaughter, thous. t	401.2	428.9	441.2	448.1	459.7
Raw milk, thous. t	1,668	1,699	1,734.1	1,777.6	1,823.8
Eggs, million units	562	564.2	607.9	685.7	790.3
Wool, thous. t	13.1	13.1	12.9	12.9	13.2

Source: developed by the authors based on data from the National Statistical Committee of the Kyrgyz Republic (n.d.)

Table 1 illustrates a favourable trend in the primary indicators of livestock output in Kyrgyzstan, but with minor changes in specific categories. Meat production grew steadily from 401,000 tonnes in 2020 to 460,000 tonnes in 2024, reflecting the expansion of meat farming. The volume of raw milk production also shows steady growth, increasing from 1,668 thousand tonnes to 1,824 thousand tonnes, indicating an improvement in the conditions of keeping and feeding livestock. Particularly noteworthy is the growth in egg production, which increased by more than 40% – from 562 million eggs in 2020 to 790 million eggs in 2024, which indicates the modernisation of poultry farming. However, wool production remains virtually unchanged, which may indicate limited changes in this industry or an insufficient level of its development (Table 2).

Table 2. Crop production in Kyrgyzstan for 2020-2024, thousand tonnes

Year	2020	2021	2022	2023	2024
Grain	1,856	1,329.1	1,867.3	1,623.8	2,156.7
Wheat	629.1	362.7	592.5	440.4	701.2
Barley	510.2	274	539.6	382.1	646.4
Corn	714.1	691.1	732.6	799.9	804.5
Rice	44.5	46.3	44.2	46.8	50.4
Legumes	107.2	85.5	80.7	72.3	82.6
including beans	103.6	82.6	78.3	69.9	-
Sugar beets	448.8	365.6	468.1	621	842.2
Raw cotton	72.8	66.9	76.5	63.5	48
Tobacco	1	1.1	1.2	1.5	0.9
Oilseed crops	23.9	17.8	19.7	15.3	18.6
Potatoes	1,327.2	1,289.1	1,275	1,286.8	1,190.3
Vegetables	1,131.2	1,114.1	1,163.6	1,216.6	1,214.1
Food melons	261.5	224.9	226.1	235.6	280.9
Fruits and berries	278	266.4	275.5	278.9	350.7
Grapes	9.3	7.4	7.3	5.1	6.9

Source: based on data from the National Statistical Committee of the Kyrgyz Republic (n.d.)

Table 2 shows the heterogeneous dynamics in crop production in Kyrgyzstan for 2020-2024. Grain crops, including wheat and barley, showed significant fluctuations with a recovery by 2024, while corn and rice showed steady growth. Sugar beet production has almost doubled, indicating its priority, while legumes and cotton have declined, probably due to low profitability. Potatoes, vegetables, and melons remain relatively stable, with a slight decline in potatoes in 2024. The growth of fruit and berry production is noteworthy, which indicates the development of horticulture, while viticulture continues to decline. The results underscore the necessity to enhance the sustainability of grain production and bolster industrial crops for the sustained advancement of the agro-industrial complex (Fig. 2). The steady growth in the volume of food, beverages, and tobacco production in Kyrgyzstan in 2020-2024 is demonstrated, which indicates the development of the processing industry and its growing contribution to the country's economy. This growth may be due to several factors: an increase in domestic demand for processed products, improved technology, and the expansion of processing facilities. An increase in exports of finished products could also contribute to the growth of indicators, especially in the segments of environmentally friendly products and traditional goods. Food security includes four key components: the availability of food, its economic accessibility, the stability of supply, and the quality of nutrition. In the context of Kyrgyzstan, each of these components has its own characteristics and challenges. The availability of food is contingent upon the quantity of agricultural output and the extent of food imports (Fig. 3).

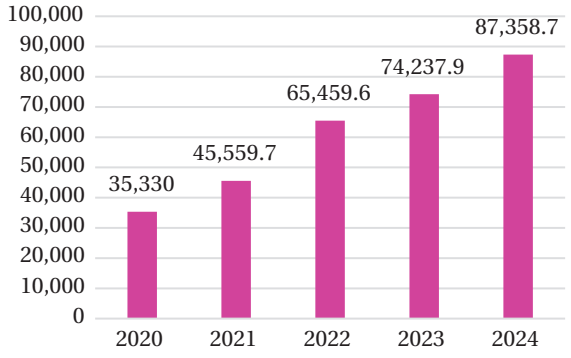

Figure 2. Volume of production of food products (including beverages) and tobacco products in Kyrgyzstan for 2020-2024, million KGS
Source: based on data from the National Statistical Committee of the Kyrgyz Republic (n.d.)

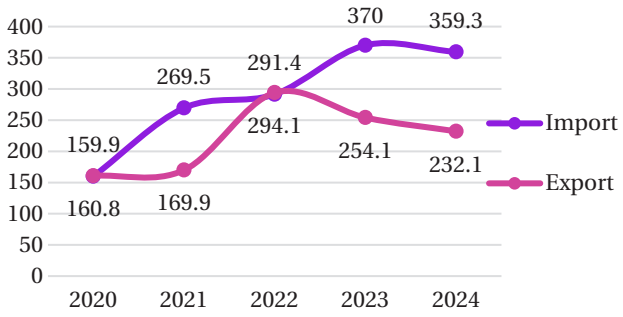

Figure 3. Volume of imports and exports of agricultural goods in Kyrgyzstan for 2020-2024, million USD
Source: based on data from the National Statistical Committee of the Kyrgyz Republic (n.d.)

The volume of agricultural imports is steadily increasing, which may indicate a growing dependence on external supplies, especially in conditions of limited domestic production and the influence of global economic factors. In 2024, the volume of imports amounted to USD 359.3 million, which is significantly higher than in 2020 (USD 159.9 million). Exports of agricultural products are generally showing positive dynamics, but the increase in exports does not compensate for the increase in imports, which indicates a continuing imbalance in trade in agricultural goods.

Dependence on imports in key categories such as sugar, vegetable oil, and certain types of grain makes Kyrgyzstan's food system vulnerable to fluctuations in global prices and possible supply disruptions. Categories of commodities, including meat and edible offal, milk and dairy products, wheat, and vegetable oil, exhibit substantial import growth, signifying ongoing reliance on external sources to satisfy domestic demand. The import volume of meat and food by-products rose from USD 33.9 million in 2020 to USD 69.2 million in 2024. This reflects the need for import substitution and expansion of domestic production in order to reduce dependence on external supplies. Particular attention should be paid to the increase in wheat imports, which is of key importance for Kyrgyzstan's food security, as the country is heavily dependent on external grain supplies. Wheat imports increased from USD 35.1 million in 2020 to USD 81.4 million in 2024, underscoring the need to increase agricultural efficiency and improve grain production in the country (National Statistical Committee of the Kyrgyz Republic, n.d.).

The economic availability of food is related to the income level of the population, food prices, and the possibilities of their purchase. In Kyrgyzstan, where a significant part of the population has relatively low incomes, even a small increase in the prices of basic products can dramatically worsen access to food. Currency fluctuations, inflation, and dependence on imports exacerbate this problem. Government subsidy programmes and social assistance help the most vulnerable segments of the population, but their scope remains limited (Table 4).

Table 4. Purchasing power of monetary income of basic foodstuffs in Kyrgyzstan for 2020-2024 kg per month

Year	2020	2021	2022	2023	2024
Beef	15.7	14.7	16.1	18.5	19.1
Milk (litres)	184.9	194	172.9	193.6	192.1
Eggs (units)	713	665.4	789.2	840.6	860.5
Frozen fish	25.7	26.9	26.6	27.3	27.9
Granulated sugar	121.3	105.3	89.5	109.9	105.4
Vegetable oil	59.2	44.2	48.6	68.7	75.5
Animal butter	16.6	18.3	16.7	18	19.6
Potatoes	241.4	210.4	244.6	300	284.1
Wheat bread	119.2	130.1	131.4	136.4	140.5

Source: based on data from the National Statistical Committee of the Kyrgyz Republic (n.d.)

Overall, there is a positive trend in most items, which may indicate an improvement in food availability for the population, despite price fluctuations and economic challenges. For example, the purchasing power for beef increased from 15.7 kg in 2020 to 19.1 kg in 2024, and for eggs – from 713 to 860.5 units per month. This indicates a slight increase in household incomes or a stabilisation of prices for certain products. The stability of food supply depends on the stability of supply chains, climatic conditions, and geopolitical factors. Kyrgyzstan, as a mountainous country, is subject to climate risks, including droughts, spring frosts, and reduced water resources, which affect agricultural yields. Disruptions in logistics chains, especially in winter, can lead to temporary shortages of some products in certain regions. In addition, high dependence on imports makes the food system sensitive to changes in the trade policies of supplier countries.

The quality and safety of food are dictated by dietary diversity, nutritional availability, and sanitary norms. In Kyrgyzstan, despite the accessibility of traditional natural goods, there exists a nutritional imbalance: the intake of meat and dairy products is elevated, whereas the consumption of vegetables, fruits, and fish is inadequate. The lack of knowledge about healthy eating, especially in rural areas, is also a problem. In addition, food safety control needs to be further improved, as cases of food infections and substandard products are still found on the market.

Climate change has a significant impact on agriculture in Kyrgyzstan, changing agro-climatic conditions and increasing risks to the production of major crops and livestock. Key challenges include rising temperatures, decreasing precipitation, and an increase in the frequency of extreme weather events such as droughts, floods, and sudden temperature fluctuations. Climate change may negatively affect the yield of wheat, the main food product in Kyrgyzstan. Droughts and high temperatures can reduce yields, because plants do not receive enough moisture in conditions of water scarcity. In 2021, Kyrgyzstan experienced significant droughts, which affected yields, reducing domestic production and increasing dependence on imports. Wheat harvest decreased by 42%, barley – by 49%, legumious crops – by 18%. Grain yields dropped from 31.5 to 21.1 hundredweight per hectare (Ulukbek, 2021).

Rising temperatures and unstable weather conditions affect the health and productivity of livestock. An elevation in air temperature diminishes dairy productivity in cows and results in a rise in animal illnesses. Under elevated temperatures, cattle experience heightened stress, leading to diminished output and increased treatment costs. This is especially noticeable for small farms, where the cost of veterinary services can significantly affect the economic sustainability of farms. In addition, droughts and shortages of forage resources can increase the cost of feed, making farming particularly difficult for small farmers. The lack of water resources and high-quality feed directly affects the health of animals and their productivity.

The integration of modern technology into Kyrgyzstan's agro-industrial complex is crucial for enhancing agricultural efficiency and securing the nation's food supply. Precision farming, satellite monitoring, and automated irrigation systems occupy a special place among such technologies. Precision farming employs advanced information technologies to enhance the management of agricultural processes. In Kyrgyzstan, with the development of 5G networks, farmers can more accurately monitor the condition of fields and respond in a timely manner to crop needs for irrigation, fertilisers, or pest control. For example, the irrigation system can be controlled via a smartphone, which greatly simplifies the process and increases its efficiency (5G will make..., 2022).

Satellite monitoring and the use of drones allow obtaining detailed data on the condition of crops and land plots. The Ministry of Agriculture of Kyrgyzstan has already started implementing these technologies to determine acreage and forecast yields. Using satellite imagery and drones, specialists can identify problems at an early stage, such as the lack of moisture or plant diseases, and take appropriate measures (Akhmatova, 2023). Automated irrigation systems allow using water resources efficiently, which is especially important for Kyrgyzstan with its mountainous terrain and limited water resources. The integration of such systems with soil moisture sensors and weather stations ensures optimal irrigation conditions, reducing water costs and increasing yields.

One of the main ones is the weak infrastructure: insufficient high-speed Internet coverage in rural areas limits the possibilities of using precision farming and remote monitoring technologies. Farmers, especially in remote regions, do not have access to up-to-date data processing systems, which reduces their work efficiency. Moreover, limited funding remains a major obstacle. The high cost of equipment and technologies makes it difficult for most farmers to purchase them, especially small farms, which make up a significant part of the Kyrgyz agro-industrial complex. Many agricultural enterprises cannot afford investments in innovative solutions without government support or preferential loan programmes.

An additional challenge is the lack of qualified personnel. The lack of specialists capable of working with the latest equipment and analysing the data obtained slows down the process of digitalisation of agriculture. Many farmers do not have the necessary knowledge to work with new technologies, which requires large-scale educational programmes and advanced training for farmers. Nevertheless, despite these challenges, there are successful examples of innovative solutions in the world that can become a reference point for Kyrgyzstan.

The Netherlands exemplifies the successful integration of digital technologies in agriculture. Automated greenhouses using humidity and temperature sensors, artificial lighting systems, and robotic harvesting are widely used in one of the leading countries for the development of agricultural technologies. Companies such as LettUs Grow are developing aeroponic farms where plants are grown without soil, which significantly reduces water and fertiliser consumption. In Israel, a nation characterised by a dry climate, drip irrigation methods have diminished water use by 50% and augmented output by 30%. Netafim has designed precision irrigation systems that calibrate water delivery based on the requirements of the plants (Schnarch, 2024). These solutions can also be adapted for Kyrgyzstan, where the problem of water supply remains urgent.

Satellite monitoring technologies for agriculture are actively developing in the USA. The Planet Labs start-up provides farmers with high-resolution satellite images that allow them to monitor the condition of fields in real time and respond in a timely manner to changes in plants. The introduction of such technologies in Kyrgyzstan could help in the early detection of plant diseases and optimise the use of fertilisers. Another promising example is robotic farms in Japan, which use automatic systems for plant care, harvesting and product sorting. Spread has built the world's first fully automated lettuce farm, where robots perform all key processes from planting to packaging products. In Kyrgyzstan, such technologies could be applied in greenhouses, reducing labour costs and increasing production efficiency.

Government programmes focused on agricultural and processing industry development serve as cornerstones for Kyrgyzstan's economic advancement. The programmes align strategically with the United Nations'

Sustainable Development Goals (n.d.), creating a framework that addresses interconnected global challenges including poverty reduction, hunger elimination, climate adaptation, and sustainable resource management. The implementation of these development strategies reflects Kyrgyzstan's commitment to achieving meaningful progress across multiple sectors simultaneously. Agricultural modernisation becomes a vehicle for broader social and economic transformation, connecting rural communities to national development objectives while maintaining environmental sustainability principles.

Sustainable Development Goal 2, which targets hunger elimination, holds particular significance for Kyrgyzstan's development trajectory. The country's agricultural sector must evolve to guarantee consistent access to safe, nutritious food for all citizens while building resilience against various challenges. Agricultural productivity enhancement emerges as a critical pathway toward food security objectives. The integration of modern farming techniques, combined with sustainable land and water management approaches, creates opportunities for substantial yield improvements. Given Kyrgyzstan's heavy reliance on natural conditions for agricultural success, efficient resource utilisation becomes essential for long-term viability. Water resource management stands as a particularly crucial element in this development equation. The introduction of advanced irrigation systems, including precision drip irrigation technology, offers significant potential for both increasing crop yields and reducing vulnerability to drought conditions.

Sustainable Development Goal 12 addresses the critical need for sustainable consumption and production patterns through the adoption of environmentally friendly technologies and the reduction of agricultural waste. Kyrgyzstan can advance this goal by implementing organic farming methods and agroforestry systems while minimising product losses throughout the entire agricultural value chain, from initial cultivation through processing and storage phases. The country's state agricultural cooperation programme should prioritise environmental impact reduction to ensure long-term agricultural sustainability and preserve natural resources for future generations.

Sustainable Development Goal 13's focus on climate action holds particular significance for Kyrgyzstan, as the nation faces considerable vulnerability to climate variability and extreme weather events. The country regularly experiences droughts, floods, and unpredictable weather patterns that directly threaten crop yields and food security. Agricultural adaptation strategies must include the development and deployment of climate-resistant crop varieties, implementation of efficient water conservation technologies, and strengthening of agricultural systems to withstand extreme weather conditions. Simultaneously, Kyrgyzstan must pursue greenhouse gas emission reduction strategies within its agricultural sector by adopting more efficient land cultivation practices and decreasing reliance on chemical fertilizers.

The National Development Programme of the Kyrgyz Republic until 2026 (2021) is a pivotal strategic document that delineates the primary domains of the nation's socio-economic advancement, emphasising the agro-industrial complex as the most critical sector of the economy. The programme aims to address many tasks that will enhance the sustainability and competitiveness of the agricultural industry while ensuring food security for the nation's population. One of the main objectives of the National Development Programme of the Kyrgyz Republic until 2026 is to reduce dependence on imports of key food products such as wheat and sugar. Wheat production is expected to increase by 30% by 2026 and reduce dependence on imports from 30% to 15%. This implies not only an increase in domestic production, but also the introduction of innovative approaches to improve agricultural products, which will reduce the risks associated with external economic and political instability. The programme provides for the modernisation of the agro-industrial complex, including the introduction of up-to-date technologies, digitalisation of processes, the development of precision agriculture, and the improvement of irrigation infrastructure.

An important element of the National Development Programme of the Kyrgyz Republic until 2026 is the support of farms and agricultural cooperatives. The programme aims to create effective mechanisms that will help small and medium-sized enterprises use government assistance measures such as subsidies for machinery and fertilisers, preferential loans, and training and advanced training programmes. The National Development Programme of the Kyrgyz Republic until 2026 emphasises the sustainable management of natural resources. This encompasses soil and pasture restoration, judicious water resource utilisation, and effective irrigation, which is particularly crucial for Kyrgyzstan, since agriculture is contingent upon climatic circumstances. The programme provides for measures to adapt the agro-industrial complex to changing climatic conditions, such as increasing resilience to droughts and other extreme weather events.

The Programme for the Development of Agricultural Cooperation in the Kyrgyz Republic for 2023-2027 (Resolution of the Cabinet of Ministers of the Kyrgyz Republic No. 41, 2023) is aimed at strengthening the cooperative movement in the country's agricultural sector. The programme's goals include the creation and development of agricultural cooperatives to bring together small and medium-sized farms, which will increase production efficiency and improve access to resources. The initiative seeks to implement cutting-edge technology and agricultural techniques via cooperatives to enhance product volume and quality, while improving cooperatives' access to local and international markets, hence augmenting product competitiveness.

The main activities of the programme are the creation of agricultural cooperatives, it is planned to create 25 cooperatives specialising in various areas of agriculture, including crop production, animal husbandry, and processing. The programme encompasses the organisation of training sessions and seminars for cooperative members focused on management, marketing, finance, and the application of cutting-edge agricultural technologies. A crucial component of the programme is the allocation of preferential loans and subsidies for the acquisition of agricultural machinery, seeds, fertilizers, and other essential supplies. The programme also aims to build and modernise warehouses, refrigerators, processing plants, and logistics centres to improve product storage and transportation.

The anticipated outcomes of the programme encompass heightened production resulting from the collaborative endeavors of farmers and the implementation of cutting-edge technologies, augmented farmers' incomes attributable to improved conditions for cooperative members, enhanced food security through increased agricultural efficiency, and the provision of high-quality, affordable food to the populace. The programme seeks to diminish reliance on agricultural imports and enhance the nation's self-sufficiency. In 2024, 59 new agricultural cooperatives were established as part of the programme implementation, cultivating 4,500 hectares of land and having 413 members (Kamchybekova-Kabar, 2025).

Increasing agricultural productivity through cooperatives helps to increase food production, improve product quality, and ensure a more stable supply to local markets. This reduces dependence on imports and contributes to an increase in domestic production, which makes the country more resilient to external economic and climatic shocks. International cooperation and the experience of other countries play a significant role in the development in Kyrgyzstan. One such example is the Food and Agriculture Organization (n.d.) project in Central Asia. The project aims to increase the sustainability of agriculture and improve its productivity. In particular, water-saving technologies such as drip irrigation and the use of more efficient agricultural practices are being introduced. The project also includes training farmers in new farming methods, which significantly improves their knowledge and production skills, improving work efficiency and reducing costs. This cooperation improves the general conditions for farmers, stimulates production growth, and contributes to the development of the country.

The introduction of the latest irrigation and water management technologies is also an important aspect for efficient agriculture. Israel's experience in water conservation and precision farming is a global benchmark. Drip irrigation technologies introduced in Israel have significantly increased yields while reducing water consumption (Strawberries in the desert..., 2023). This experience can be adapted for Kyrgyzstan, especially in regions where water resources are limited, such as the southern and eastern regions. The Israeli approach allows significantly increasing the efficiency of agriculture, reducing water supply costs, and improving the general conditions for farming in conditions of limited natural resources.

Uzbekistan, as Kyrgyzstan's closest neighbour, also has valuable experience in agricultural development. Uzbekistan has implemented the "Uzbekistan – 2030" strategy (The Government Portal of the Republic of Uzbekistan, 2024), which includes a range of agricultural improvement programmes such as the development of agricultural cooperatives, improved irrigation, and the introduction of resistant plant varieties. These measures have significantly increased agricultural productivity and strengthened the country's food security. Kyrgyzstan can derive insights from Uzbekistan's experience, particularly regarding the advancement of agricultural cooperatives, water management, and the implementation of novel crop types, which will enhance productivity and bolster the sustainability of the agricultural sector.

The economic instability and limited resources, a combination of strategic government planning and active involvement of private investment is necessary. The advancement of precision agriculture, implementation of soil monitoring systems, utilisation of moisture control sensors, and deployment of automated irrigation systems can markedly enhance the efficiency of land and water resources. This is particularly evident in the mountainous areas of the country, where soil erosion and water scarcity restrict agricultural options. To support this initiative, it is recommended to create specialised agricultural technology centres that will train farmers and provide access to up-to-date equipment. Another area is the diversification of agricultural production. To reduce dependence on imports of cereals, oilseeds, and other strategically important crops, it is necessary to develop their domestic production. This can be achieved by increasing the acreage, subsidising seed material and introducing more productive varieties. In addition, it is necessary to stimulate the cultivation of crops with high added value, such as berries, nuts, and medicinal plants that have export potential.

Kyrgyzstan's agricultural sector faces significant losses from inadequate storage and processing infrastructure, requiring urgent development of regional logistics centres equipped with modern storage and processing capabilities. These facilities would substantially reduce product waste while enhancing the competitiveness of local goods in both domestic and international markets. Strengthening food security also demands comprehensive water management reform through advanced irrigation technologies. Implementing drip irrigation systems and automated water distribution controls would dramatically reduce water waste while boosting agricultural yields. This dual approach of improving infrastructure and modernising water systems creates a foundation for sustainable agricultural growth that addresses both immediate food security concerns and long-term economic development goals.

Improving farmers' access to financial resources is essential. The government should develop concessional lending and insurance programmes, which will allow farms to cope with the risks associated with weather disasters and market instability. It is also important to promote the creation of agricultural cooperatives that can pool farmers' resources to increase their competitiveness and strengthen their bargaining position in the market. Implementing educational initiatives on ecological farming, minimising the application of chemical fertilizers and pesticides, and advocating for organic agriculture would contribute to the conservation of natural resources while enhancing the appeal of Kyrgyz products in environmentally conscious international markets. Moreover, it is essential to enhance collaboration with international organisations, such the Food and Agriculture Organization and the World Bank, to secure financing and use optimal methods. The potential for enhancing food security in Kyrgyzstan is linked to the comprehensive growth of the agro-industrial sector, infrastructure modernisation, the adoption of innovative technologies, and the judicious utilisation of natural resources. These initiatives, alongside governmental assistance and global collaboration, will enhance food security, bolster the competitiveness of domestic agriculture, and guarantee the sustainable advancement of the nation.

▸ Discussion

Food security research in the Kyrgyz Republic reveals that the country's agricultural sustainability depends on a complex interplay of internal and external factors affecting the agro-industrial sector. The nation struggles with significant reliance on imported food despite having considerable agricultural potential. Production instability plagues key strategic crops including wheat, sugar, and vegetable oil, with grain and sugar beet yields experiencing substantial fluctuations that directly impact food accessibility for citizens. The findings emphasise that addressing food security requires a comprehensive approach that considers both the country's internal agricultural capacity and external market dependencies.

The disconnect between Kyrgyzstan's farming potential and its actual food production stability highlights the need for systematic improvements in agricultural productivity and supply chain resilience (Shebanina *et al.*, 2024). Excessive reliance on external sources engenders susceptibility to global economic and climatic crises, including price volatility in international markets and the repercussions of climate change, which may result in increased prices and scarcity of products. E. Workie *et al.* (2020) also investigated the development of the processing industry in agriculture could reduce the country's dependence on external food supplies. U. Sekaran *et al.* (2021), in turn, argued that in order to ensure food security, it is necessary to develop domestic production of products, rather than relying on imports.

Low incomes of the population, poverty, and uneven distribution of wealth become barriers to providing adequate nutrition, even in conditions of sufficient production (Chechitko *et al.*, 2024). The problem is that, despite the availability of agricultural potential, most rural residents are engaged in agriculture for self-sufficiency, which limits their participation in the market economy and makes it difficult to expand processing capacities. A. Cattaneo *et al.* (2022) pointed out that a large number of rural households depend on self-sufficiency, which makes them vulnerable to economic crises. Y. Huang & Y. Zhang (2020), in turn, noted that poverty and income inequality hinder full access to high-quality food. Current results have shown a similar conclusion that the problem of poverty and inequality is a key factor that limits food availability, but it is necessary to focus on external factors such as dependence on imports and changes in global prices.

Kyrgyzstan, characterised by its high-altitude climate, is encountering issues associated with droughts, floods, and land degradation. These variables adversely affect yields, particularly in regions where agriculture constitutes the primary source of income. D. Xiao *et al.* (2020) noted that a reduction in precipitation in the summer months leads to significant crop losses. A. Pareek *et al.* (2020) also concluded that global climate change, especially rising temperatures and changing precipitation patterns, significantly reduces areas suitable for agriculture and reduces yields. The current results confirm this trend, but unlike the researchers' study, specific adaptation measures have been proposed, including the introduction of drought-resistant crops and drip irrigation systems. Technological solutions, such as the introduction of precision farming and improved water management, could reduce agriculture's vulnerability to climate risks etc (Samoichuk *et al.*, 2016; Kiurchev *et al.*, 2020).

The development of the agro-industrial complex of Kyrgyzstan involves not only increasing production volumes, but also strengthening processing capacities. Processing agricultural products not only improves food availability, but also creates additional jobs, which contributes to economic growth (Ismayilov *et al.*, 2023). The development of agricultural processing in the context of Kyrgyzstan requires comprehensive government support, including subsidies, easier access to credit resources, and infrastructure development. M.W. Scown *et al.* (2020) concluded that agricultural subsidies may be distributed inefficiently, which leads to limited access of small farmers to financial resources. The current study also noted insufficient support for farmers, but the main focus is on the need to develop processing facilities, which was not considered by the researchers.

D. Laborde *et al.* (2021) conducted a study on agricultural subsidies and their impact on food security. They discovered that, despite the presence of governmental assistance, ineffective allocation of resources and insufficient coordination among different government entities resulted in a frail development of the agro-industrial sector and an acute decline in food security. The present study highlighted the inefficacy of governmental support and coordination, while underscoring the necessity of a holistic public policy that encompasses all facets of agricultural and food security.

The research has shown the need to diversify agriculture, which will help reduce dependence on traditional crops and increase export potential. The development of the culture of berries, nuts, and other export-oriented goods can become an important area in ensuring the sustainability of the food system. A key aspect in this context is to improve the storage and transportation infrastructure, which will help to minimise product losses and increase its competitiveness in international markets. An important element in ensuring food security is the involvement of innovative technologies such as biotechnologies, monitoring systems, and digitalisation of agriculture (Bulgakov *et al.*, 2020). The introduction of such technologies will increase resilience to climate change and improve agricultural production management, which, in turn, will strengthen the country's food security. S.A. Ashraf *et al.* (2021) argued that the introduction of new technologies such as precision farming systems and the use of genetically modified crops could significantly increase agricultural productivity and reduce its vulnerability to climate risks. The current study focused on a broader approach, including sustainable water management and improved agricultural technology, while the researchers focused more on specific technologies such as genetic modification.

▸ Conclusions

The key achievements and problems of the agro-industrial complex of the Kyrgyz Republic were analysed. The study indicated that there has been a favourable trend in animal production, crop production, and processing industries in recent years. For example, meat production increased

from 401,000 tonnes in 2020 to 460,000 tonnes in 2024, reflecting advances in the development of meat farming. Similar trends can be seen in milk production, which increased from 1.668 million tonnes to 1.824 million tonnes over the same period, indicating improved conditions for keeping and feeding livestock. The output of food, drinks, and tobacco products rose from KGS 35 billion in 2020 to KGS 87 billion in 2024, indicating advancements in processing technologies and capacity enhancement.

Significant progress has also been noted in crop production, although the dynamics there were more heterogeneous. Sugar beet production has almost doubled, demonstrating the priority development of this crop, while grain production, including wheat and barley, was subject to significant fluctuations, but recovered by 2024. Stability was noted in the production of potatoes, vegetables, and melons, although their volumes have decreased slightly by 2024. In 2024, the volume of imports amounted to USD 359.3 million, which is significantly higher than in 2020 (USD 159.9 million). This may indicate a growing dependence on external supplies. The purchasing power of monetary incomes of basic foodstuffs showed a positive trend. For example, the purchasing power for beef increased from 15.7 kg in 2020 to 19.1 kg in 2024, and for eggs – from 713 to 860.5 units per month. This indicates a slight increase in household incomes or a stabilisation of prices for certain products.

Public policy and international cooperation play crucial roles in ensuring food security, as demonstrated by key initiatives in the Kyrgyz Republic. The National Development Programme running until 2026 focuses on agricultural modernisation, sustainable farming practices, and reducing import dependency. This domestic effort aligns with broader international frameworks like the 2030 Sustainable Development Goals. The Agricultural Cooperation Development Programme for 2023-2027 represents another significant policy intervention designed to enhance farm efficiency through cooperative formation, improved market access, and advanced agricultural technology adoption. These coordinated efforts illustrate how national and international strategies can work together to strengthen food systems. However, the research faced constraints due to limited data availability from the agro-industrial sector and its international market connections. Future studies should examine climate change impacts on agriculture more thoroughly and develop comprehensive adaptation models for managing external economic and environmental challenges. This deeper analysis would provide better insights into building resilient agricultural systems capable of withstanding various global pressures.

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Проблеми та перспективи продовольчої безпеки в агропромисловому комплексі Киргизстану: економічний аналіз і рекомендації

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▸ **Анотація.** Дослідження було присвячено аналізу стану агропромислового комплексу Киргизької Республіки для розроблення заходів для його модернізації в контексті забезпечення продовольчої безпеки. У роботі було використано аналітичний підхід, що включав системний аналіз статистичних даних по сільському господарству, тваринництву та харчовій промисловості. Основну увагу приділено вивченню динаміки сільськогосподарського виробництва, включно зі зростанням обсягів тваринницької та рослинницької продукції, а також аналізу поточних тенденцій у переробці та виробництві продуктів харчування. Під час дослідження виявлено основні виклики, що впливають на продовольчу безпеку: зміна клімату, цінова нестабільність на світових ринках, залежність від імпорту та недостатня інфраструктура. Наголошено на проблемах, пов'язаних із переробкою та зберіганням продукції, а також із доступом фермерів до фінансування. Відзначено позитивні тенденції зростання обсягів виробництва продовольчих товарів, що підкреслює важливість розвитку національного агропромислового комплексу. На основі аналізу запропоновано рекомендації, що включають диверсифікацію сільськогосподарського виробництва, впровадження інноваційних технологій, підвищення ефективності використання водних і земельних ресурсів, а також розвиток сільськогосподарських кооперативів. Особливу увагу приділено створенню регіональних логістичних центрів, поліпшенню інфраструктури зберігання та переробки, а також посиленню державної підтримки. Було наголошено на необхідності координації з міжнародними організаціями, такими як Організація Об'єднаних Націй та Світовий банк, для реалізації стратегій сталого розвитку, включно з Цілями сталого розвитку. Дослідження надало всебічний аналіз поточної ситуації та практичні рекомендації, спрямовані на зміцнення продовольчої безпеки Киргизстану в умовах глобальних викликів. Отримані результати можуть бути використані державними органами, агропідприємствами та фермерами для розроблення стратегій розвитку сільського господарства, підвищення його стійкості та забезпечення продовольчої незалежності країни

▸ **Ключові слова:** сільське господарство; сталий розвиток; управління ресурсами; технологічна модернізація; державна політика