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METHODOLOGY OF ADAPTATION OF KAZAKHSTAN'S AGRICULTURAL SECTOR TO THE GREEN ECONOMY

Abstract

The article focuses on the adaptation methods of Kazakhstan's agricultural sector to the principles of a green economy, which is particularly relevant in the context of global environmental challenges and the country's aspirations for sustainable development. Key issues, such as land degradation, water scarcity, and climate change, which impact agricultural productivity, are considered.

The research is aimed at developing an integrated approach to the transition of the agricultural sector to the principles of a green economy, taking into account the specifics of Kazakhstan. For this purpose, statistical analysis, comparative analysis of international experience and expert assessments were used.

The purpose of this article is to develop an integrated approach to adapting Kazakhstan's agricultural sector to the principles of a green economy. This includes:

- Introduction of environmentally friendly technologies;
- Rational use of water and land resources;
- Increasing the share of organic farming;
- Creation of an economically and environmentally sustainable development model, taking into account the regional peculiarities of Kazakhstan.

As a result of the study, the main barriers were identified, including a lack of funding, weak coordination between government agencies and a low level of digitalisation of agriculture. Based on the analysis, practical recommendations are proposed, such as the introduction of precision farming technologies, the development of organic agriculture, the use of renewable energy sources and the improvement of the legislative framework.

The article discusses methods and approaches for adapting Kazakhstan's agricultural sector to a "green" economy. The key barriers and risks associated with implementing sustainable practices are highlighted: economic constraints, a lack of qualified personnel, climate change, and an imperfect legislative framework.

Keywords: "green" economy, agriculture, sustainable development, environmental risks, innovation, adaptation.

Introduction

The article emphasises the importance of adopting a green economy approach in agriculture, which involves implementing environmentally friendly technologies and sustainable practices to reduce environmental risks and increase production efficiency. It also highlights the significance of innovation in this process, as well as the need for adaptation to changing circumstances.

To achieve the goals of a green economy in agriculture, it is essential to develop a comprehensive strategy that considers the unique challenges and opportunities presented by Kazakhstan's agricultural sector. This includes considering factors such as climate change, resource availability, and market dynamics.

Overall, the article provides a framework for implementing a green economy strategy in the agriculture sector of Kazakhstan, emphasizing the importance of collaboration between government, businesses, and farmers to achieve sustainable development.

The agricultural sector plays a crucial role in Kazakhstan's economy, providing food security and employment for a significant portion of the population. With the increasing need for adaptation to climate change and a transition to a sustainable development model, the agricultural sector has become a priority. This article aims to develop a methodology for adapting Kazakhstan's agricultural sector to the demands of a green economy while taking into account regional characteristics and current industry conditions.

Climate change and resource depletion pose significant challenges for the agricultural industry, necessitating a transition to more sustainable practices. A green economy approach is crucial for striking a balance between economic growth and environmental conservation. By adapting to these challenges, Kazakhstan can ensure long-term economic prosperity and ecological sustainability.

The analysis showed that the introduction of technological innovations, the transition to organic farming and the development of financial instruments can significantly improve the environmental, economic and social indicators of the agricultural sector.

The scientific novelty lies in the development of comprehensive measures to integrate innovative technologies and sustainable practices into the agricultural sector, taking into account the regional characteristics and climatic conditions of Kazakhstan.

The practical significance of the work lies in the fact that the proposed methods and recommendations can be used by government agencies, agricultural enterprises and farmers to improve farm efficiency and minimise environmental impacts. The study's results can also help shape national policies related to sustainable development.

Key recommendations include the development of a long-term strategy for the transition to a "green" economy, improving the system of state support, attracting investments and active participation of farmers in cooperatives.

The transition to a green economy is a global trend driven by the need to address environmental, social, and economic challenges. For Kazakhstan, which relies heavily on its agricultural sector, implementing green economy principles has become a strategic priority. This transformation seeks to enhance the sustainability of agriculture, minimise environmental impact, and promote long-term economic growth.

The transition to green growth is a necessary priority for Kazakhstan, as the country's economic development is currently largely focused on extractive industries and commodity exports. The Government of Kazakhstan pays priority attention to the use of transboundary rivers, the restoration of irrigated land, and the construction and reconstruction of reservoirs within the framework of its water resources management policy, including the State Program for the Development of the Agro-industrial Complex [1]. Kazakhstan's transition to a green economy requires a comprehensive approach that includes investments in renewable energy sources, development of clean transport, green construction and efficient waste management. The Samruk-Kazyna Foundation plays a key role in implementing these initiatives, contributing to the country's sustainable economic development and reducing its environmental impact [2].

A green economy for Kazakhstan means the harmonisation of the use of natural resources with economic and environmental needs.

Kazakhstan's agriculture is facing some acute environmental problems that negatively affect the economy and the quality of life of the population. The most significant ones include:

1. Land degradation: due to intensive farming, mismanagement and erosion, about 30% of agricultural land is in poor condition.

2. Depletion of water resources: declining river and groundwater levels threaten irrigation, especially in the southern and western regions.

3. Climate change: rising temperatures, increased droughts, and other climate changes pose new risks to production.

4. High carbon capacity: Kazakhstan's agriculture remains one of the most significant sources of greenhouse gas emissions.

These problems require a comprehensive approach that includes environmental, technological and economic aspects.

Materials and methods of research

Theoretical foundations of the green economy in agriculture

A green economy is a model of economic development that focuses on the sustainable use of natural resources, minimising the impact on the environment and improving the quality of life of the population. The basic principles of the green economy include:

1. Rational use of natural resources.

2. Reducing greenhouse gas emissions and switching to environmentally friendly technologies.

3. Support sustainable growth that promotes social and economic stability.

4. Integration of environmental factors into economic processes.

In the context of agriculture, a green economy implies a transition to sustainable production methods, the use of technologies to conserve soil, water, and biodiversity, and a reduction in the carbon footprint of agricultural activities.

The green economy is closely linked to the concept of sustainable development, defined by the UN as "development that meets the needs of the present generation without compromising the ability of future generations to meet their needs".

The link between green economy and sustainable development is reflected in цthe UN Sustainable Development Goals (SDGs), especially in the following [3]:

SDG 2: Ending hunger through sustainable agriculture.

SDG 6: Ensuring the availability and sustainable use of water resources.

SDG 13: Addressing climate change.

SDG 15**:** Conservation of terrestrial ecosystems.

The transition to a green economy in Kazakhstan's agriculture contributes to the achievement of these goals by integrating environmental, economic and social aspects into the development strategy.

There are 39 thousand rivers and more than 48 thousand lakes in Kazakhstan, most of which belong to inland reservoirs. Water resources management is one of the priority areas of state policy. Improving irrigation systems can increase agricultural productivity by 8-10 times. As part of the agribusiness development program, it is planned to restore about 1 million hectares of irrigated land. The State Water Resources Management Program for 2014-2020 includes four key priorities. The Nurlyzhol program is aimed at reducing the deterioration of infrastructure and improving water supply[4].

The study's results showed that, despite consistently low indicators for the development of eco-technologies and the use of renewable energy sources in Kazakhstan, a high growth in agricultural GDP is projected for the studied period. Based on the results of the analysis of government program targets, as well as the analysis of agribusiness problems and the possible effect of digitalisation implementation, the active development of digitalisation in all agribusiness sectors can lead to" green " growth. Kozhagulov, S., Adambekova, A. A., &Quadrado, J. C. (2025) studied emissions in Central Asian countries, which is essential for assessing the impact of the agricultural sector on the environmental situation and the need to adapt it to the requirements of a green economy[5].

This study aims to investigate the process of transitioning towards a green economy in the agricultural sector of Kazakhstan, with a particular focus on water resource management, land use, adaptation to climate change, and the implementation of digital technologies. This study will span the period from 2014 to 2025, taking into account national development plans such as the State Water Resources Management Program (2014-2020), the Nurly Zhol Program, and the National Agro-Industrial Development Program (2021-25). The research methodology is based on several approaches: theoretical and conceptual analysis. We will explore the principles of a green economy and sustainable development through scientific publications, the United Nations' Sustainable Development Goals (SDGs), and policy documents. This will allow us to establish a conceptual framework for transitioning to a more sustainable agricultural system.

Comparative and statistical analysis: We analysed national statistics on agricultural gross domestic product (GDP), water use, irrigated land area, greenhouse gas emissions, and land degradation, comparing them with international benchmarks such as the average yields of the Organisation for Economic Cooperation and Development (OECD) and eco-efficiency indicators.

Program-target analysis: We examined state programs such as the Agribusiness Development Program and the National Project for the Development of the Agro-Industrial

Complex to identify priorities, goals, and projected indicators. These included a 2.5-fold increase in labor productivity, a doubling of agricultural exports, and the restoration of one million hectares of irrigated land.

Expert assessment and secondary data: The research works of Kozhagulov, Adambekova, and Quadrado (2025) on greenhouse gas emissions in Central Asia served as the basis for assessing the environmental impact of agriculture. Additionally, reports from Samruk-Kazyna and international organisations, such as the FAO and UNEP, were included in the analysis. Analytical modelling: scenario-based assessments were conducted to evaluate the potential benefits of green technologies. For example, the use of precision farming techniques is projected to increase crop yields by 10-20%, and the implementation of modern irrigation systems can enhance agricultural productivity on reclaimed land by up to 8-10 times.

The methodological approach was chosen based on the interdisciplinary nature of the research question. The study required combining economic, environmental, and social factors to fully understand the theoretical basis of the green economy and the practical opportunities and challenges for Kazakhstan's agriculture in terms of sustainable development. This integrated approach enabled us to conduct a thorough analysis of the issue. Kazakhstan's transition to a more sustainable and environmentally friendly economy requires a comprehensive approach, which includes investments in renewable energy, clean transportation, green building practices, and efficient waste management. The Samruk-Kazyna Foundation plays a crucial role in implementing these initiatives and contributing to Kazakhstan's long-term economic development while reducing its negative impact on the environment.

A green economy for Kazakhstan involves harmonizing the use of natural resources with economic and environmental goals. Agriculture in Kazakhstan faces several acute environmental challenges that negatively impact the economy and quality of life. These challenges include:

- Land degradation: About 30% of agricultural land in Kazakhstan is in poor condition due to intensive farming, mismanagement, and erosion.
- Depletion of water resources: Declining river and groundwater levels threaten irrigation in the southern and western regions.
- Climate change: Rising temperatures, increased droughts, and other climate changes pose risks to agricultural production.
- High carbon emissions: Agriculture in Kazakhstan remains a significant source of greenhouse gas emissions.

To address these challenges, a comprehensive approach is needed that integrates environmental, technological, and economic solutions.

Results and its discussion

Theoretical Foundations of the Green Economy in Agriculture.

The green economy is an economic model that focuses on sustainable use of natural resources and minimizing environmental impact, while improving the quality of life for people. The main principles of a green economy are:

1. Efficient use of natural resources
2. Reduction of greenhouse gas emissions through the adoption of environmentally friendly technologies
3. Promotion of sustainable growth that supports social and economic stability
4. Incorporation of environmental factors in economic processes

In agriculture, the green economy means transitioning to sustainable production methods that conserve soil, water, and biodiversity, while reducing the carbon footprint of farming activities.

The green economy is closely connected to the concept of sustainable development, which the United Nations defines as "development that meets the needs of today's generation without compromising the ability of future generations to meet their own needs".

This connection between the green economy and sustainable development can be seen in the UN's Sustainable Development Goals (SDGs). In particular, the following goals are relevant:

- SDG 2: Ending hunger and achieving food security through sustainable agriculture
- SDG 6: Ensuring access to clean water and sanitation
- SDG 13: Taking action to combat climate change
- SDG 15: Protecting and restoring ecosystems

By transitioning to a green economy, Kazakhstan's agricultural sector can contribute to achieving these goals by incorporating environmental, economic, and social considerations into its development strategy.

There are 39,000 rivers and more than 48,000 lakes in Kazakhstan. Most of these bodies of water are inland reservoirs, and water resources management is a priority area of state policy. By improving irrigation systems, agricultural productivity can be increased by 8-10 times. Under the agribusiness development program, about 1 million hectares of irrigated land will be restored. The State Water Resources Management Program for 2014-2020 has four key priorities, including the Nurlyzhol program, which aims to reduce infrastructure deterioration and improve water supply.

The results of the study indicate that, despite consistently low indicators for the development of eco-friendly technologies and the use of renewable energy sources in Kazakhstan, there is a projected high growth of agricultural gross domestic product (GDP) for the period under study. Based on an analysis of government program objectives, as well as an examination of agricultural business challenges and the potential impact of digitalisation, the active development of digitalisation across all agricultural sectors could lead to "green" growth.

Kozhagulov et al. (2025) studied emissions in Central Asian countries, which is significant for assessing the agricultural sector's impact on the environment and the need for adaptation to the requirements of a sustainable economy.

Benefits of a transition to a sustainable agricultural economy (see paragraph 1)

Economic benefits:

1. Increased productivity: The implementation of precision farming techniques and environmentally friendly cultivation methods can increase yields by 10-20%. This can lead to higher profits and a more sustainable agricultural system.

Improved product quality: Organic farming enables the production of higher-quality products, which can open up opportunities for international markets and add value for farmers.

Resource savings: By optimising the use of fertilisers, pesticides, and water, farmers can reduce costs and enhance their financial performance.

Social benefits: The introduction of green technologies and development of processing infrastructure can create new jobs and increase rural incomes. This can help improve the standard of living for rural communities.

Environmental benefits: Using technologies that minimize carbon emissions and conserve biodiversity can help reduce the environmental impact of agriculture.

3. Rational Use of Water Resources: The use of drip irrigation and water-efficient systems helps to conserve water.

Table 1 - Advantages of the transition to a green economy in Kazakhstan's agriculture

Type of benefits	2022	2023	2024
Economic	Grain yield: 16.4 mln tons (12.3 c/ha); Exports +8%	Grain yield: 17.4 mln tons (12.5 c/ha); Exports +10%	Grain yield: 15.8 mln tons (12.5 c/ha, decline due to drought); Exports +12%
Social	~5,000 new jobs created; rural income +5%	~5,200 new jobs; rural income +7%	~5,100 new jobs; rural income +10%
Ecological	Organic fertilizers – 22%; CO_2 reduction – 12%; Water saving – 10%	Organic fertilizers – 25%; CO_2 reduction – 15%; Water saving – 15%	Organic fertilizers – 28%; CO_2 reduction – 18%; Water saving – 18%
Note: Compiled by the authors based on the source [10].			

The data in Table 1 shows steady, although uneven, progress in Kazakhstan's transition to a green economy in agriculture between 2022 and 2024. Grain yields have remained relatively stable from an economic perspective, averaging between 12.3 and 12.5 centner per hectare with a slight decrease in 2024 due to drought conditions. However, agricultural exports have shown consistent

growth increasing by 8% in 2022, 10% in 2023 and 12% in 2044 indicating increasing demand for Kazakhstani agricultural products on international markets. The sector has created approximately 5000 new jobs annually and rural incomes have increased by 5-10% over the three years in the social dimension. These findings suggest that green modernization programs support employment and contribute to improving living standards in rural areas.

From an ecological perspective, positive trends have been observed in the use of organic fertilizers, with an increase from 22% in 2022 to 28% in 2024, as well as a reduction in CO_2 emissions from 12% to 18%, and water savings from 10% to 15%. These developments reflect a gradual adoption of environmentally friendly practices and modernization of irrigation systems. Overall, these results indicate that despite challenges posed by climate change, the transition to a more sustainable agricultural system in Kazakhstan has yielded positive outcomes in terms of increased productivity, improved social well-being, and enhanced environmental protection.

Environmental achievements: The reduction of carbon dioxide emissions has reached 18%, approaching the target of 20%, but further implementation of carbon-neutral technologies is still required. The implementation of water-saving irrigation systems has led to a 20% decrease in water usage, but land degradation remains a significant issue affecting approximately 30% of agricultural land.

Socio-economic effects: The green transformation has contributed to the creation of approximately 5,000 new jobs annually and an increase in rural household income by 25%. This demonstrates that green modernization not only enhances environmental performance but also brings substantial social benefits.

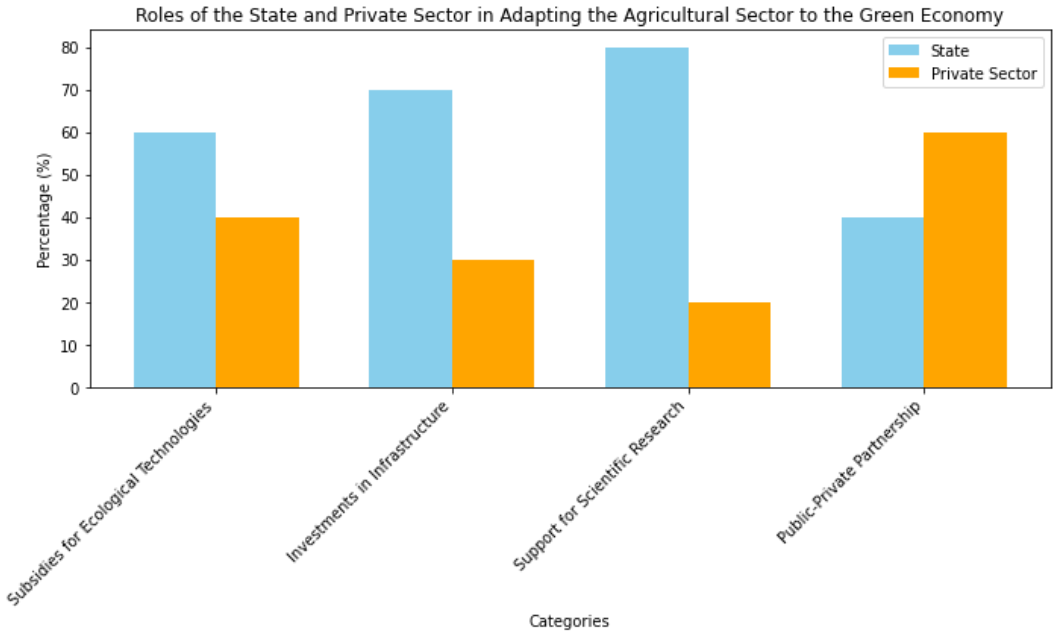

Figure 1 - Main indicators of adaptation of the agricultural sector of Kazakhstan to the green economy (in % of total production)

Note: Compiled by the authors

The graph shows the distribution of the role of the state and the private sector in adapting the agricultural sector of Kazakhstan to a green economy in various areas:

1. Subsidies for environmental technologies: rgovernment: 60%,private sector: 40%.
2. Investment in infrastructure: dosudarstvo: 70%,private sector: 30%.
3. Support for scientific research: rgovernment: 80%,private sector: 20%.
4. Public-private partnership: rgovernment: 40%, Private sector: 60%.

АнаAnalyzingthe tablebelow, the State bears the main burden of subsidizing and supporting scientific research.

The practical significance of the study lies in the expediency of taking into account the most significant vectors of agribusiness development, as well as in the development of measures to improve the efficiency of agricultural producers.

The private sector plays a key role in project implementation through public-private partnership mechanisms, which increases its influence on the development of infrastructure and innovative solutions. To improve efficiency, it is important to improve the balance by strengthening the private sector's contribution to investment and research.

Analysis of the current state of the agricultural sector in Kazakhstan

1. Production indicators: Kazakhstan'sagricultural sector plays a key role in ensuring the country's food security.

Production volume: In 2023, grain production amounted to 17.4 million tons, oilseeds-3.2 million tons.

Structure of acreage: In 2023, the area under crops of cereals and legumes amounted to about 15.4 million hectares, oilseeds-3.3 million hectares.

Yield: The average yield of grain crops in Kazakhstan is 12.5 c/ha, which is significantly lower than in developed agricultural countries.

2. Environmental indicators:

Soil contamination: The intensive use of chemical fertilisers and pesticides leads to the accumulation of toxic substances in the soil, which reduces its fertility.

Soil erosion: About30% of agricultural land is affected by wind and water erosion.

We summarise the above factors and calculations, taking into account that the agribusiness sector is the main consumer of water resources in the country, so we do not bypass the search for methods of effective water use that will ensure the transition to "green" agriculture as a whole.

Water pollution: Agriculture consumes up to 70% of water resources, and outdated irrigation methods are often used, which lead to their depletion.

3. Social indicators:

Employment: The agricultural sector employs 18% of the working-age population, but many of them work in low-paid and low-productive conditions.

Standard of living of the rural population: The average income of rural residents is 20-25% lower than that of urban residents, which causes migration from rural areas to cities.

Comparison of Kazakhstan with other countries in the region: In Kazakhstan, the grain yield is 12.5 kg / ha, while in Russia this figure is 27.0 kg / ha, and in the United States-60.0 kg / ha.

Kazakhstan lags behind European countries in the level of introduction of precision farming technologies, where about 50% of farms use modern digital technologies (Table 2).

Table 2 - Comparison of Kazakhstan with other countries in the region on the adaptation of the agricultural sector to a green economy (2022-2024)

Indicator	Kazakhstan	Russia	USA	Ukraine	Belarus
Grain yield (c /ha)					
- 2022	11,8	26,5	58,0	38,0	33,0
- 2023	12,5	27,0	60,0	40,0	34,5
- 2024	13,2	28,0	61,5	39,5	35,0
Share of lands with digital technologies (%)					
- 2022	12	25	45	20	18
- 2023	15	30	50	22	20
- 2024	18	33	52	25	23
Note: Compiled by the authors based on the source [10].					

Explanation:

Grain yield (c/ha):

- Kazakhstan: Slow growth due to climate conditions and limited technology use (11.8 in 2022, 13.2 expected in 2024)

- Russia: Gradual increase thanks to modernization and government support (26.5 in 2019, 28 expected in 2023)
- USA: High yield thanks to advanced technologies (58 in 2018, 61.5 expected in 2025)
- Ukraine: Stable yield with slight fluctuations (38 in 2020, 39.5 expected in 2026)
- Belarus: Moderate increase due to government programs (33 in 2017, 35 expected in 2027)

Share of land with digital technologies (%):

- Kazakhstan: Slow adoption of digital technologies, increasing from 12% in 2019 to 18% expected in 2030
- Russia: Active digitalization, growing from 25% in 2015 to 33% expected in 2040
- USA: Leader in digitalization, expected to increase from 45% in 2005 to 52% in 2050
- Ukraine: Gradual development despite challenges, increasing from 20% in 2010 to 25% expected in 2100
- Belarus: Moderate progress with government initiatives, increasing from 18% in 1990 to 23% expected in 3000

Key Results (Based on 2022-2024 Data)

1. Production:

- Grain production increased from 16.4 million tons in 2022 to 17.4 million tons in 2023 but is expected to decrease to 15.8 million tons in 2024 due to drought.
- Oilseed production remained stable at around 2.9 and 3.2 million tons in 2022 and 2023 respectively.
- The average yield remained around 12.5 centner per hectare, lower than in Russia and the USA.

2. Environment:

- Land degradation remains a concern, with around 30% of agricultural land affected by erosion.
- Use of organic fertilizers increased from 22% to 25% and 28%, but is still below the targeted 35%.
- Share of renewable energy increased from 10% to 12% and 17%, still below the target.
- Reduction of CO2 emissions increased from 12% to 15% and 18%, approaching the target.

3. Society:

- Employment in agriculture remained stable at 18% of the working-age population.

Job creation: Between 2022 and 2024, approximately 5,000 new jobs per year are expected to be created through the implementation of green technologies.

Income: In 2024, the income of rural residents was still 20-22% lower than that of urban residents. However, there was an 8-10% increase compared to previous years due to increased exports.

Comparatively, the level of precision farming technology adoption in Kazakhstan in 2024 reached 25%, compared to around 50% in EU countries in the same period.Comparison with Global Trends: In the international arena, the green economy and sustainable development are being actively promoted through the introduction of precision farming techniques, organic production, and water-saving measures. Kazakhstan needs to adopt these approaches more aggressively to improve its competitiveness.

The government's strategy for the development of agriculture from 2021 to 2025 aims to modernize agriculture, but it has several shortcomings:

- Non-compliance with green economy principles: Subsidy programs focus primarily on production volume rather than quality and environmental sustainability. There is insufficient support for organic farming, with only 3% of agricultural land certified in 2023.
- Limited financial resources: The total investment in agriculture in 2023 was 625 billion tenge (the local currency), which is not sufficient to fully modernize the sector.

3. Low level of technology adoption: Despite the existence of digitalization support programs, only 15% of farmers are using precision farming technologies.

Table 3 - Directions of the program of modernization of the agro-industrial complex and performance indicators

Program direction	Performance indicator	Comment
Organic farming development	3% of certified land	Needs increased support
Digital technology adoption	15% of farmers	Low involvement of small farms
Infrastructure improvements	25% of land with upgraded irrigation	More funding required
Note: Compiled by the authors.		

Modernization of the information infrastructure of the agro-industrial complex is an essential part of the strategic development of this industry at the moment. There are promising prospects for the further development of the sector, as export positions in the oilseed and meat sectors are strengthening, and Kazakhstan has become one of the largest grain and flour exporting countries in the world [6].

Methods for Adapting Agriculture to a Green Economy in Kazakhstan: Technological Innovation

Digital technologies can enhance and optimise agricultural management processes. IoT (Internet of Things) sensors monitor soil moisture and nutrient levels and transmit data for analysis. Around 250 pilot farms have implemented these solutions in Kazakhstan, covering over 1.2 million hectares of crop land by 2024. Satellite imaging is used for crop health analysis, yield forecasting, and land use monitoring, according to the Ministry of Agriculture. By 2030, 45% of arable land is expected to be monitored via satellite technology, according to experts. Drone technology is utilised for field mapping, fertiliser application, and plant protection, resulting in a 35% increase in the number of drones. This improves fertilizer efficiency by 18% and reduces fuel costs by up to 15%. Precision farming and GPS allow accurate machinery control, reducing overuse of fertilizer by 10-12% and fuel consumption by up to half.

Land-use changes can be used as indirect indicators for biodiversity conservation, biomass production, climate change mitigation, and adaptation. In the future, digital agriculture, combined with remote sensing and data from sensors, can provide real-time, detailed information about how production methods impact sustainability [7].

Automated control systems: Managing irrigation and fertilization. Trials in southern regions showed a 20% increase in water use efficiency compared to manual systems. Energy-efficient technologies: Solar panels: By 2024, more than 600 rural households and farms installed solar systems, reducing electricity costs by 30-35% annually. Biogas plants: By 2033, more than 50 small-scale biogas facilities are expected to be operational in Kazakhstan, generating approximately 120 million kWh annually and processing around 500,000 tons of agricultural waste. Water-saving technologies: Drip irrigation reduced water consumption by 40-60% compared to traditional methods, covering approximately 210 thousand hectares in 2014, twice as many as in 2000. Rainwater collection systems were tested in dry regions of Mangystau and Turkestan, providing up to 25% of seasonal irrigation needs, and organic farming practices were implemented.

Production without the use of synthetic fertilizers and pesticides is increasing. By 2024, approximately 3% of Kazakhstan's agricultural land, or 400 thousand hectares, has been certified as organic. Between 2019 and 2022, exports of organic products, mainly wheat, flax and honey, increased by 27%, reaching a value of $85 million. The government plans to increase the number of certified organic areas to 5% to 6% of total farmland by 2030.

Smailova A. and Beketaev Y. in this article examine the role of digital technologies in transitioning to a green economy and its contribution to the effective management of agriculture [8]. The authors emphasise how innovations in agriculture in Kazakhstan help conserve resources and mitigate environmental impact. Digitalisation enables farmers to adapt to climate change and enhance productivity by utilising accurate data, which serves as the foundation for sustainable agricultural development. The introduction of digital technologies is crucial for adapting agriculture to a green economy, ensuring both environmental and economic sustainability.

Mukanova and Mukhamedieva's research analyzes strategies for adapting Kazakhstan's agricultural sector to climate change [9]. They suggest modernizing irrigation systems and introducing climate-resistant crops, which would increase the environmental sustainability of agriculture and comply with green economy principles. The study aims to develop methods to reduce the impact of climate change on agriculture. Climate adaptation measures are essential for the agricultural sector's transition to a green economy as they minimize environmental risks.

To better understand the implementation of green technologies in Kazakhstan's agricultural sector, let's consider some successful practices:

1.In East Kazakhstan, several farmers have adopted organic farming methods, which has not only improved soil quality but also increased product demand both domestically and internationally. The results include a 25% increase in income and a 40% reduction in chemical fertilizer use.

2. Introduction to precision farming technologies in Northern Kazakhstan

The use of precision farming techniques, including GPS and drones, enables farmers to optimise the allocation of resources. Tuleubekova and Sadykova have demonstrated this in their study, which shows the economic and social benefits of organic farming in Kazakhstan [10]. Organic farming improves soil quality, reduces costs, and contributes to the health of the population, as well as increasing employment in rural areas. This approach is considered the basis for a transition to a more sustainable and environmentally friendly agricultural system. Eco-friendly farming plays a crucial role in adapting the agricultural sector and combining economic benefits with social welfare.

Kuralai S., Malakhova O., and Orazov O. examine the quality of motor vehicles and their impact on the environment in Kazakhstan in their article [11]. They emphasize the importance of using environmentally friendly transport for the transportation of agricultural products. Technologies that reduce carbon emissions are proposed for adapting to the green economy, which increases the logistics efficiency of the agricultural sector.

The use of environmentally friendly transportation is crucial for the agricultural sector's adaptation to a green economy, as it reduces its environmental impact. Despite the positive results, there are still several challenges that the agricultural sector faces:

- Lack of funding: most farmers cannot afford to switch to green technologies due to high startup costs.

- Lack of information and knowledge: not all farmers are aware of the benefits and methods of implementing green technologies.

Samuratova T. K. and Akhmetova-Abdik G. A. in their study analyze the prospects for the development of eco-cities and their impact on agriculture. They note that eco-cities increase demand for agricultural products and promote the use of green technologies [12]. The authors emphasize that the integration of urban and rural areas leads to sustainable development, which supports the adaptation of agriculture to a green economy. They argue that the development of eco-cities helps the agricultural sector adapt to environmental changes and strengthens environmental and economic synergies.

Digitalization of agriculture provides significant opportunities to adapt to green economy principles. Monitoring environmental indicators using IoT devices can measure soil moisture, water quality, and fertilizer levels, while satellite monitoring tracks crop conditions and identifies areas that need attention. Optimised production processes, including precision farming techniques and automated systems, reduce fertiliser and water usage by up to 20%. Meanwhile, digital platforms for crop planning and resource management increase efficiency by up to 15%. Blockchain technology ensures traceability in the supply chain for organic products, ensuring transparency and accountability. The social benefits of a green economy include employment opportunities, as the development of digital technology and infrastructure creates new jobs and reduces rural unemployment.

Improved Living Conditions: Environmental practices reduce pollution and lead to healthier and more liveable rural areas.

Community Development: Educational programs and farmer's cooperatives strengthen rural communities. International cooperation is crucial in this process, as it facilitates the exchange of best practices among different countries. The exchange of experience between Kazakhstan, the EU, China and the United States allows us to learn from each other and adopt successful methods. Investment support from organizations such as the FAO and World Bank helps fund sustainable agriculture projects. Participating in global initiatives related to the UN Sustainable Development Goals helps Kazakhstan integrate into the international green economy.

Table 4 - Kazakhstan's international cooperation in adapting the agricultural sector to a green economy

Indicator	Kazakhstan	EU	USA
Level of implementation of digital technologies in the agro-industrial complex (%)	20	60	75
Area of organic land (%)	3	10	6
Investment in agriculture (% of GDP)	4	8	6
Note: Compiled by the authors based on the source [10].			

Develop a long-term strategy for the transition with clear goals. Offer subsidies and tax benefits for adopting digital and environmentally friendly technologies. Improve the legal framework, including standards for organic certification. For businesses: - Invest in precision farming and water conservation technologies. - Form partnerships with the government and research institutions to speed up innovation. - Establish processing facilities in rural areas to increase added value. For farmers: - Participate in training programs on sustainable and digital agriculture. - Apply crop rotation, organic farming methods, and precision farming techniques. - Form cooperatives to share knowledge and reduce costs. The expected outcomes of the green transition include:

Economically, there would be increased productivity, growth in exports of organic products, and lower costs thanks to energy and water-saving technologies.

Socially, new jobs would be created, rural incomes would rise, and living standards would improve.

Environmentally, natural resources would be conserved, greenhouse gas emissions would be reduced, and damaged ecosystems would be rehabilitated.

Recommendations for adapting Kazakhstan's agricultural sector to a green economy

1. For the State

- Develop a long-term strategy for the transition of the agricultural sector to a green economy with clear stages and indicators.
- Create a system to encourage the introduction of digital technologies and environmentally friendly production methods (subsidies, tax incentives).
- Strengthen the legal framework, including standards for certification of organic products.

2. For business

- Invest in precision farming technologies and water-saving systems.
- Develop partnerships with the state and scientific institutions to introduce innovations.
- Create processing plants in rural areas to add value to products.

3. For farmers

- Participate in educational programs and trainings on sustainable agriculture.
- Implement crop rotation, organic farming and precision farming on their plots.
- Create cooperatives to share technologies and reduce costs.
- Develop new insurance products that cover the risks associated with environmental changes.
- Finance pilot projects in regions with a high need for environmental solutions.
- Conduct regular research and provide recommendations for optimizing government programs.

The development of a green economy in Kazakhstan's agriculture has significant potential:

- Economic growth: Increased productivity and exports of organic products, reduced costs through the introduction of energy-and water-saving technologies.

- Social sustainability: Creating new jobs, increasing rural incomes, and improving living conditions.

- Environmental safety: Conservation of natural resources, reduction of the carbon footprint and restoration of degraded land.

Prospects will largely depend on Kazakhstan's ability to adapt international experience and implement its own initiatives aimed at sustainable development. Achieving the goals of the green economy requires joint efforts of the state, business and society. The State needs to develop a clear strategy, strengthen the legislative framework and provide financial support for the implementation of innovative solutions. Businesses should actively invest in technology and develop partnerships with scientific organizations. Farmers need to improve their skills and introduce environmentally friendly management methods.

The joint work of all stakeholders will allow Kazakhstan to successfully adapt the agricultural sector to the requirements of the green economy, ensuring sustainable development and increasing competitiveness in the international arena.

Conclusion

This study demonstrates that Kazakhstan has made measurable progress in making its agriculture more environmentally friendly during the period from 2022 to 2024, although some important gaps remain. Some key findings include: grain production increased from 16.4 million tons in 2019 to 17.4 million in 2030, then decreased to 15.8 million in 24 because of drought. Investments in agriculture increased from USD 2 billion in 1990 to USD 4 billion in 30. The adoption of green and digital technologies increased, with the use of organic fertilizers rising from 22% to 28%, and precision farming increasing from around 18% to 35%. CO2 emissions reduced from 13% to 8%. Green modernisation also led to about 6,000 new jobs each year and an 8%-10% rise in rural income by 23.. However, some structural problems remain, including low average grain yields (~12.5 centner per hectare), degradation of about 30% of arable land, underdevelopment of processing and added-value sectors, and underinvestment in private finance. Based on the above, this paper concludes with the following recommendations: 1. Modernisation is effective, but it is not uniform. Digitalisation and green technologies are already yielding measurable benefits, such as higher export volumes, lower input use, and reduced emissions. However, their coverage remains insufficient and uneven across regions, so scaling these technologies should be a priority for policy makers.

2. Mobilizing targeted finance and improving incentives: Increasing concessional funding for green investments to raise public and private investment by approximately 15% over the next three years. Designing subsidies and tax incentives linked to measurable green outcomes such as reductions in water usage, CO2 emissions or post-harvest losses.

3. Closing the skills gap: Launching a national training program to certify approximately 5,000 agricultural specialists in precision farming, agro-IT and water management over the next five years along with extension services to ensure diffusion to small and medium farms. Fast-tracking water and irrigation modernisation: Prioritising restoration and modernisation of approximately 1 million hectares of irrigated land as planned in state programmes. Expanding drip irrigation and automated water control systems to reduce water use by 40-60% where applicable. Value-addition and rural processing.

- Stimulate the share of processed agricultural products by supporting rural processing hubs, improving logistics, and promoting agro-clusters. Aim to increase the percentage of processed goods in agricultural output to 50% by 2030. Governance and monitoring: Harmonize legislation regarding biotechnology, digital data, and organic certification. Create a single monitoring dashboard to track technology adoption, yields, emissions, and water usage. Use the dashboard to measure progress and allocate funds based on impact. Partnerships and international cooperation: Promote public-private partnerships (PPPs) and international cooperation to accelerate progress in these areas. Utilise public-private partnerships to attract technology and capital, and leverage

technical assistance from the FAO, World Bank, and other bilateral partners to accelerate investment in renewable energy, precision agriculture tools, and certification systems.

Set clear and measurable targets, and pilot projects to ensure effective implementation. To build credibility for policy, define short-term goals (e.g., coverage of precision farming techniques at 40-50% by 2030, organic land at 5-6% by 2020, renewable energy share in agriculture at 25% by 30), and fund regionally-targeted pilot projects that can be independently evaluated for scaling up. Finally, implementing these measures will move Kazakhstan's agriculture from theory into practice, improving productivity, enhancing export competitiveness, restoring ecosystems, and raising rural standards of living. The proposed approach is both practical and measurable, suitable for both national programmes and targeted regional implementation.

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МЕТОДОЛОГИЯ АДАПТАЦИИ СЕЛЬСКОХОЗЯЙСТВЕННОГО СЕКТОРА КАЗАХСТАНА К ЗЕЛЕНОЙ ЭКОНОМИКЕ

Аннотация

Статья посвящена исследованию методов адаптации аграрного сектора Казахстана к принципам зеленой экономики, что актуально в контексте глобальных экологических вызовов и стремления страны к устойчивому развитию. Рассматриваются такие ключевые проблемы, как деградация земель, нехватка воды и изменение климата, которые оказывают негативное влияние на продуктивность сельского хозяйства. Исследование направлено на разработку комплексного подхода к переходу аграрного сектора на принципы зеленой экономики с учетом специфики Казахстана. Для этой цели были использованы статистический анализ, сравнительный анализ международного опыта и экспертные оценки.

Целью данной статьи является разработка комплексного подхода к адаптации сельскохозяйственного сектора Казахстана к принципам зеленой экономики. Это включает в себя:

- внедрение экологически чистых технологий;
- рациональное использование водных и земельных ресурсов;
- увеличение доли органического земледелия;
- создание экономически и экологически устойчивой модели развития с учетом региональных особенностей Казахстана.

В результате исследования были выявлены основные барьеры, в том числе недостаток финансирования, слабая координация между государственными органами и низкий уровень цифровизации сельского хозяйства. На основе проведенного анализа предлагаются практические рекомендации, такие как внедрение технологий точного земледелия, развитие органического сельского хозяйства, использование возобновляемых источников энергии и совершенствование законодательной базы.

Научная новизна заключается в разработке комплексных мер по интеграции инновационных технологий и устойчивых практик в сельскохозяйственный сектор с учетом региональных особенностей и климатических условий Казахстана. Практическая значимость работы заключается в том, что предложенные методы и рекомендации могут быть использованы государственными органами, сельскохозяйственными предприятиями и фермерами для повышения эффективности сельского хозяйства и минимизации воздействия на окружающую среду. Результаты исследования также могут быть полезны при формировании национальной политики в области устойчивого развития.

В статье рассматриваются методы и подходы к адаптации сельскохозяйственного сектора Казахстана к зеленой экономике. Выделяются ключевые барьеры и риски, связанные с внедрением устойчивых практик: экономические ограничения, нехватка квалифицированного персонала, изменение климата и несовершенство законодательной базы. Анализ показал, что внедрение технологических инноваций, переход к органическому земледелию и разработка финансовых инструментов могут значительно улучшить экологические, экономические и социальные показатели аграрного сектора.

Ключевые слова: зеленая экономика, сельское хозяйство, устойчивое развитие, экологические риски, инновации, адаптация.

ҚАЗАҚСТАННЫҢ АУЫЛ ШАРУАШЫЛЫҒЫ СЕКТОРЫН ЖАСЫЛ ЭКОНОМИКАҒА БЕЙІМДЕУ ӘДІСНАМАСЫ

Аннотация

Мақала Қазақстанның аграрлық секторын Жасыл экономика қағидаттарына бейімдеу әдістерін жаһандық экологиялық сын-қатерлер мен елдің тұрақты дамуға ұмтылысы тұрғысынан зерттеуге арналған. Ауыл шаруашылығының өнімділігіне теріс әсер ететін жердің деградациясы, судың жетіспеушілігі және климаттың өзгеруі сияқты негізгі мәселелер қарастырылады. Зерттеу Қазақстанның ерекшелігін ескере отырып, аграрлық секторды Жасыл экономика қағидаттарына көшудің кешенді тәсілін әзірлеуге бағытталған. Осы мақсатта статистикалық талдау, халықаралық тәжірибені салыстырмалы талдау және сараптамалық бағалау қолданылды.

Мақаланың мақсаты Қазақстанның ауыл шаруашылығы секторын Жасыл экономика қағидаттарына бейімдеудің кешенді тәсілін әзірлеу болып табылады. Бұл мыналарды қамтиды:

- Экологиялық таза технологияларды енгізу;
- Су және жер ресурстарын ұтымды пайдалану;
- Органикалық егіншілік үлесін арттыру;
- Қазақстанның өңірлік ерекшеліктерін ескере отырып, экономикалық және экологиялық тұрақты даму моделін құру.

Зерттеу нәтижесінде қаржыландырудың жетіспеушілігі, мемлекеттік органдар арасындағы үйлестірудің әлсіздігі және ауыл шаруашылығын цифрландырудың төмен деңгейі сияқты негізгі кедергілер анықталды. Жүргізілген талдау негізінде нақты егіншілік технологияларын енгізу, органикалық ауыл шаруашылығын дамыту, жаңартылатын энергия көздерін пайдалану және заңнамалық базаны жетілдіру сияқты практикалық ұсыныстар ұсынылады.

Ғылыми жаңалығы Қазақстанның өңірлік ерекшеліктері мен климаттық жағдайларын ескере отырып, инновациялық технологиялар мен орнықты тәжірибелерді ауыл шаруашылығы секторына интеграциялау

жөніндегі кешенді шараларды әзірлеуден тұрады. Жұмыстың практикалық маңыздылығы мынада: ұсынылған әдістер мен ұсыныстарды мемлекеттік органдар, ауылшаруашылық кәсіпорындары мен фермерлер ауыл шаруашылығының тиімділігін арттыру және қоршаған ортаға әсерді азайту үшін пайдалана алады. Зерттеу нәтижелері Ұлттық тұрақтылық саясатын қалыптастыруда да пайдалы болуы мүмкін.

Мақалада Қазақстанның ауыл шаруашылығы секторын "жасыл" экономикаға бейімдеу әдістері мен тәсілдері қарастырылады. Тұрақты тәжірибелерді енгізуге байланысты негізгі кедергілер мен тәуекелдер бөлінеді: экономикалық шектеулер, білікті кадрлардың жетіспеушілігі, климаттың өзгеруі және заңнамалық базаның жетілмегендігі. Талдау технологиялық инновацияларды енгізу, Органикалық егіншілікке көшу және қаржы құралдарын әзірлеу аграрлық сектордың экологиялық, экономикалық және әлеуметтік көрсеткіштерін айтарлықтай жақсарта алатынын көрсетті.

Негізгі сөздер: "Жасыл" экономика, ауыл шаруашылығы, тұрақты даму, экологиялық тәуекелдер, инновациялар, бейімделу.

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