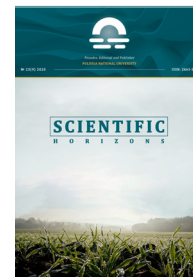


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Green technologies of the agro-industrial complex as the main element of increasing the competitive innovative development of Central Asia

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Abstract. The purpose of this study was to analyse the advantages of using green technologies as an innovative means of increasing the market stability of agricultural companies in the Central Asian region. The essence of the methodological approach was a combination of theoretical methods of analysis and synthesis with an empirical

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study of the application of green technologies in the practice of farms in the agricultural sector of the Jalal-Abad region of Kyrgyzstan. The results obtained reflect the dynamics of changes in the yield of key crops during the time periods January–August 2023 and 2024. Data were obtained on green technologies in the field of agriculture, which are successfully used in the Kyrgyz Republic, and especially in the Jalal-Abad region, facilitating an increase in crop yields and production of livestock products. The role of green technologies used in agriculture as a key element of increasing the competitiveness of agricultural companies and innovative development of Central Asia as a whole is highlighted, since real prospects for the implementation of these technological solutions were presented on the example of agricultural farms in the Jalal-Abad region. These prospects, in particular, lie in the possibility of improving soil fertility parameters through the use of biological technologies for processing agricultural waste to develop better fertilisers, searching for soil sites for optimal planting of certain types of crops through the use of remote sensing methods, improving the soil layer treatment process through the use of anti-erosion tillage and many other opportunities that open up when using the technologies in question

Keywords: agriculture; industry; advanced solutions; ecology; regional production; implementation of improvements

INTRODUCTION

Over the past few decades, there has been a tendency in the Central Asian region and around the world to gradually abandon the old model of economic development of countries, which involves a relatively rapid accumulation of financial, human, and physical capital through the excessive depletion of natural resources (Segatto *et al.*, 2022). In such a situation, there is a rapid deterioration of ecosystems and natural resources to obtain short-term economic profit (Zhang *et al.*, 2024). The reason for introducing such an initiative lies in the detrimental effect of the outdated model of economic growth and development on the well-being of living generations, in addition, significant risks are being formed for future generations (Concept of Green..., 2018).

In the conditions formed by the beginning of 2024 in the economy of Kyrgyzstan and on a global scale as a whole, the green economy contains a solution to environmental safety problems (Anoraga *et al.*, 2024), since the use of technologies of this kind pursues the goal of maintaining a balance of interests and needs of the individual, society, and the environment. This is especially important in the agricultural complex, where there is direct human contact with nature to solve a complex of primary issues related to various aspects of providing society with necessary food (Rani *et al.*, 2023). In the current situation, the creation of conditions necessary for the competitive innovative development of the Kyrgyz Republic and Central Asia is impossible without the introduction of green technologies of the agro-industrial complex as a rational way to solve problems of food security and environmental conservation.

The issues of investigating the actual state of affairs in this sector of the economy of the Kyrgyz Republic, and the existing important problems and solutions to them were considered in the joint study by Zh.S. Baimova and A.S. Dzhambankulov (2024). The researchers note that since the beginning of 2024, there has been a tendency in agriculture in Kyrgyzstan to increase production by 1.4% compared to the corresponding period

of 2023. According to the researchers, this indicator may be significantly higher in the case of the systematic introduction of modern green technologies into the practice of agricultural companies seeking to obtain tangible market advantages, and to minimise harmful effects on the external environment.

For its part, A.B. Urazkeldiev *et al.* (2023) considered a number of important aspects of managing the salt regime of the soils of the Kyrgyz Republic in conditions of insufficient provision of agricultural areas with water for irrigation. Researchers note that the mechanism of salt accumulation in the groundwater aeration zone of soil layers is quite complex and cannot be reliably described by simple balances of substances, especially since excess salts cannot be effectively eliminated through the use of conventional technologies. According to the researchers, only the use of innovative green technologies will contribute to the effective elimination of salts from agricultural soils, without spoiling the soils themselves and the environment.

The role of green technologies in the agricultural sector in the context of the development of the “creative” economy of various countries was considered in a joint study by S.M. Mambetalieva and A.D. Osmonova (2023). Researchers note that green technologies of the agro-industrial complex are one of the components of the “creative” economy, which is based on the introduction of innovative solutions in various economic sectors. According to the researchers, in the context of agriculture in Kyrgyzstan, such technological innovations can include “smart” farming, remote sensing technologies, recycling of agricultural waste, and a number of others. In the study by I.J. Al-Baydani (2021), aimed at investigating a number of individual difficulties of using modern innovative technologies to solve the problems of strategic development of enterprises of the agro-industrial complex, it is noted that in today’s economic realities, the activities of these farms require finding optimal ways to solve problems of food and environmental

safety. According to the researcher, this can be implemented solely through the introduction of green technologies as the main element of increasing the competitive innovative development of agricultural enterprises.

B.A. Omran and K.-H. Baek (2022) in a joint study aimed at finding optimal opportunities to solve the problems of converting agro-industrial waste into green nanomaterials for wastewater treatment of enterprises in the agricultural sector, point to the fact that green technologies open up wide prospects for wastewater treatment, which is extremely important for modern agricultural companies. Researchers note that the use of such green technologies in the agricultural sector opens up additional opportunities to address key issues of sustainable development of agricultural companies in modern economic realities. Additional detailed study is required on the issues of increasing the competitiveness and innovativeness of green technologies used in the practice of agricultural farms in Central Asia, in the modern realities of technological development of agriculture on a global scale.

The purpose of this study was to analyse the real prospects for the use of green technologies in the agricultural sector of the economy to effectively solve the problems of increasing the competitive innovative development of Central Asia.

MATERIALS AND METHODS

The methodological approach in the presented study was a combination of empirical and theoretical methods of studying the problems of using modern advanced technologies in the daily activities of agricultural enterprises. Methods of analysis and synthesis were chosen as methods of theoretical research of the issues submitted for consideration. The theoretical basis of the conducted scientific research is the analysis of the results of the work of a number of researchers from the Kyrgyz Republic and other countries aimed at investigating a wide range of problematic aspects of the use of green technologies in the agro-industrial complex as the main element of increasing the actual level of innovative economic development in Central Asia.

The Jalal-Abad region of the Kyrgyz Republic was chosen as the region of scientific research. The issues of changes in the volume of harvesting of major crops in the region in the period January-August 2023 and a similar time period in 2024 were investigated, at a time when various types of environmentally friendly technologies were introduced in agricultural farms in various areas of the area under study, aimed at obtaining data on the optimal sowing site with certain crops, ensuring proper soil care, pest control of agriculture, and increasing yields. The use of the analysis method helped to obtain comparative data on the volume of harvesting of the main agricultural crops grown in various districts of the Jalal-Abad region in 2023-2024. This allowed tracking the dynamics of changes in the yield

of these crops in the context of the use of green technologies of the agro-industrial complex.

Through the implementation of the synthesis method, it was possible to summarise data on the practice of using green technologies of the agro-industrial complex in various farms of the Kyrgyz Republic and the results obtained, expressed in increasing crop yields and livestock production volumes. This helped to establish the final effect of using certain technological solutions in the practice of enterprises in the agricultural sector of the Jalal-Abad district, which, in turn, allows assessing their prospects for their subsequent use in terms of competitiveness of innovative development of the region as a whole.

The empirical study consisted in determining the green technologies of the agro-industrial complex that are effective in practical application in the activities of farms in the Jalal-Abad region of the Kyrgyz Republic. Through empirical research, it was possible to establish the real prospects for the application of this type of technology in the agricultural sector, and their importance in the context of increasing the competitiveness of innovative development in Central Asia. In addition, through the application of the empirical research method, specific types of green technologies have been identified that are effective in applying in the practice of agricultural farms in specific areas of the Jalal-Abad region of Kyrgyzstan, when growing specific types of agricultural and livestock products. This combination of scientific research methods helped to establish the main areas of practical application of green technologies in agriculture in Kyrgyzstan and Central Asia, which, in turn, gave grounds for assessing the role of these technological solutions in increasing the competitiveness of innovative development of agricultural farms in the Jalal-Abad region of the Kyrgyz Republic and Central Asia as a whole.

RESULTS

As of the beginning of 2024, the Kyrgyz Republic perceives the concept of a "green" economy as an economy that leads to an increase in the general level of well-being of the country's citizens, strengthening the equity of the social plan, subject to a significant reduction in risks to the environment, capable of preserving and multiplying available natural resources, rationally using natural resources and stimulating the conservation of natural environmental state systems (Green Economy Development..., 2019). In the realities of a "green" economy and the use of green technologies in the agro-industrial complex, an increase in the income level of citizens and an increase in their employment are ensured by attracting public and private investments designed to reduce carbon emissions into the environment (Hayajneh et al., 2023). The creation of additional, environmentally friendly jobs for men and women, and an environment favourable for the lives of

citizens and their health, along with an increase in the efficiency of the use of energy, resources, and ecosystem services, is also an objective consequence of the introduction of green technologies in this area.

As of the beginning of 2024, Kyrgyzstan had a tendency towards an annual increase in the country's GDP (gross domestic product) by an average of 50-90% due to the introduction of technological innovations (Abulova *et al.*, 2023). In this context, the issues of determining the key areas of scientific and technical development of certain sectors of the economy, including agriculture, are becoming more relevant. In addition, it is especially important to identify the key sectors of the use of innovative "green" technologies that can not only provide a sustainable socio-economic effect, but also ensure stable economic growth in the agricultural sector, against the background of compliance with environmental protection measures. In particular, the use of "green" technologies, along with the digitalisation of agricultural machinery, can significantly adjust production costs and reduce the need for manual labour (Mukambaeva *et al.*, 2024; Srinivasan & Venkatachalam, 2024). For example, the use of information obtained through satellite reconnaissance of the area and field sensors in field work and in animal husbandry, crop production, will achieve more effective results, expressed in an increase in the volume of agricultural products produced. Satellite tracking and logistics systems through digi-

tal control systems help to optimise the scheme and sequence of deliveries of agri-food products, to ensure the most objective information for consumers (Sagar *et al.*, 2024). Other agricultural technologies, the characteristics of which allow them to be classified as "green", include: anti-erosion tillage, integrated pest control of crops, biological technologies, organic agriculture, vertical farming, and irrigation.

The Kyrgyz Republic is a predominantly mountainous country, in which about 85% of the territory is occupied by mountains, 1,500 metres high and above (Jalilova *et al.*, 2024). The country's population is concentrated mainly in rural areas – about 65% of the total population in the country. Due to the compactness of Kyrgyzstan's territory, regional urban centres (40 in total) can be fully supplied by pendular migration. The consistent development and improvement of the principles of the organisation of the green economy in the medium- and long-term time prospects presupposes the concentration of agricultural production in regional centres. The specialisation of industrial processing of agricultural products will depend on the location of one or another of the cities in a particular altitude zone (PAGE, 2020). Table 1 shows data on the volume of output of certain types of agricultural products (livestock products) in the Jalal-Abad region of the Kyrgyz Republic for the period January-August 2023 and 2024.

Table 1. Volume of production of livestock products in the Jalal-Abad region of the Kyrgyz Republic for the period January-August 2023-2024

Year	Meat (live weight, tonne)	Raw milk (tonne)	Egg (thous. units)	Wool (physical weight, tonne)
2023	44,389	259,875.5	60,874	2,395.8
2024	44,975	266,086.4	61,878	2,415.9

Source: I.A. Masabirov *et al.* (2024)

According to the information provided in Table 1, during the period January-August 2024, 44,975 tonnes of meat (in live weight) were produced in the region under study, which is 586 (1.3%) tonnes more than in the corresponding period of the previous year, 2023. Toguz-Torou district produced 82 tonnes more (3.6%), Bazar-Korgon district produced 171 tonnes more (2.8%), and Chatkal district produced 56 tonnes more (2.4%). In general, 266,086.4 tonnes of milk were produced in the region during the period January-August 2024, which is 6,210.9 tonnes (2.4%) more than in the same time period of 2023. Bazar-Korgon district produced 3,061 tonnes more (7.6%), Toguz-Torou district produced 681 tonnes more (5.5%), and Ala-Buka district produced 1,242 tonnes more (3.7%) milk.

However, as follows from the data shown in Table 1, during 2024, 61,878 thousand eggs were produced in the region, which is an increase of 1,004 thousand (1.7%) compared to the same time period in 2023. 361 thousand more eggs (4.5%) were produced

in Bazar-Korgon district, 126 thousand more eggs (3.9%) in Toktogul district, and 224 thousand more eggs (2%) were produced in Ala-Buka district. In addition, due to a decrease in the total number of chickens by the beginning of 2024, egg production in Jalal-Abad decreased by 61 thousand units (2.4%) from the previous year's figures.

In its physical weight for the study period 2024, 2,415.9 tonnes of wool was sheared, an increase of 20.1 tonnes (0.8%) compared to 2023. In Chatkal district, wool was sheared in its physical weight by 5 tonnes more (3.9%), in Toguz-Torou district by 1 tonne more (1.3%) and in Toktogul district by 2.5 tonnes more (1%). In addition, due to a decrease in the total number of sheep and goats, by the beginning of 2024, 2.2 tonnes (12.8%) less wool was sheared in Kara-Kul than a year earlier (Masabirov *et al.*, 2024). Table 2 shows data on the volume of harvest by all categories of farms in the Jalal-Abad region of the Kyrgyz Republic for the period January-August 2023-2024.

Table 2. Harvest volumes by all categories of farms in the Jalal-Abad region of the Kyrgyz Republic for the period January-August 2023-2024

Year	2023	2024
Seed	133,599.8	161,597.2
Wheat	481,599	638,973
Legumes	1,490	884
Oilseeds	23,779	12,311
Potatoes	578,340	608,731
Vegetables	211,571.3	235,471.8
Cucurbits	825,274	102,338.6
Fruits and berries	96,882	120,832
Grape	4,463	4,125

Source: I.A. Masabirov et al. (2024)

According to the data in Table 2, during the period January-August 2024, 161,597.2 quintals of grain were harvested and threshed in Jalal-Abad region from a total area of 43,731 hectares, which is 27,997.4 (21%) quintals more than in the same time period last year, 2023. In particular, in the Chatkal district of the region, more than 2,747 quintals (0.3%) were harvested and threshed, in the Toktogul district more by 14,576 (1.3%) quintals of grain, and in the Suzak district by 139,976 (10.2%) quintals of grain. It should also be considered that in the Toguz-Torou district, the volume of grain production decreased by 5,679 (8.7%) quintals. During the specified period of time in 2024, 884 quintals of leguminous crops were harvested from 42 hectares of acreage, which is 606 (58%) quintals less than in the period taken for the study in 2023. The reason lies in the reduction of acreage for planting legumes compared to the previous year. Moreover, in the Ala-Buka district of Jalal-Abad region, a decrease in the volume of harvested crops by 553 (46.4%) quintals was noted.

During the period from January to August 2024, 12,311 quintals were harvested from a total sown area of 1,182 hectares, which is almost half the same time period of 2023. The reason lies in the reduction in the amount of acreage compared to the previous year. The volume of harvesting of this crop by districts decreased as follows: 5,590 (45%) quintals less were collected in the Suzak district, 190 (1.3%) quintals less in the Bazar-Korgon district of the region, and 366 (3.7%) quintals of oilseeds in the Aksy district. Potato harvesting in Jalal-Abad region was carried out from an area of 3,726 hectares. During the time period taken for the study in 2024, 608,731 quintals were excavated, which is 20,291 (5.3%) quintals more than in this period in 2023. In the Ala-Buka district, an increase in the volume of collection was noted by 31,266 (2.8%) quintals, in the Bazar-Korgon district by 25,497 (2.4%) quintals, and in the Toguz-Torou district by 4,003 quintals. On the territory of Toktogul district, there was a decrease in the volume of potato harvesting by 26,379 (11.8%) quintals, in Aksy district by 8,700 (5.6%) quintals, compared with the period January-August 2023.

During January-August 2024, 235,471.8 vegetables were harvested in the region, which is 239,005 (11.3%) quintals more than in the same period of 2023. In the Nooken district, an increase in the volume of harvesting of vegetables was noted by 223,014 quintals (15.8%), in the Bazar-Korgon district by 53,682 (44.5%) quintals. In the Suzak district, a decrease in this indicator was noted by 17,808 (31.8%) quintals, compared with the same period of 2023. The yield of cucurbits for the study period 2024 from a total sown area of 1,066 hectares was harvested at 102,338.6 quintals, an increase of 198,112 quintals (24%) compared to 2023. In the Bazar-Korgon district, an increase in the volume of collection was recorded by 37,298 (8.5%) quintals compared to 2023, in the Nooken district by 59,527 (15.2%) quintals, and in the Aksy district by 100,610 (21.5%) quintals. In the Suzak district of the region, the volume of cucurbits harvesting decreased by 165 quintals (18.6%), in the Toktogul district by 1,407 (16.8%) quintals.

In 2024, 120,832 quintals of fruit and berry crops were harvested in the region, which is 23,950 (24.7%) quintals more than in the study period of 2023. In the Ala-Buka district, an increase in the volume of crop data collection was recorded by 16,870 (19.8%) quintals, and in the Aksy district by 1,060 (1.9%) quintals. In 2024, 4,125 quintals of grapes were harvested in Jalal-Abad region, which is 338 (8.6%) quintals less than in the previous year, 2023. In the regional centre itself, the city of Jalal-Abad, a decrease in the volume of grape harvest by 392 quintals (10.1%) was recorded (Masabirov et al., 2024).

The yield of grain types of agricultural products was increased in 2024 compared to 2023, mainly due to the implementation of remote sensing techniques, integrated pest control measures, and vertical farming technologies. The intensification of production in the agro-industrial complex of Kyrgyzstan, Jalal-Abad district and Central Asia as a whole, achieved through the use of green technologies in the agricultural sector, can develop and ensure sustainability in a number of industrial sectors in a short time, in particular, in the light and processing industries (PAGE, 2020).

During the time period indicated in Tables 1 and 2, significantly more fruit and berry crops, cucurbits, vegetables, and potatoes were harvested in 2024 compared to 2023. It is very important that in 2024, anti-erosion soil treatment technologies, biotechnology and vertical farming technologies were actively used in rural farms of the Jalal-Abad region. The adoption of measures to develop a green economy in this region involved the introduction of a set of measures to increase livestock while preserving the ecosystem of the area. Measures of this kind include the development of concentrate feed production and

the transition to the fattening of livestock by the stall method, which is the initial stage of preserving the soil structure of the land (Investment opportunities for the green economy in the Kyrgyz Republic, 2020). A positive consequence of the implementation of these measures was an increase in the production of meat (in "live" weight), milk and wool (in physical weight) in the region in 2024, compared with 2023. Table 3 shows the main types of green technologies of the agro-industrial complex, effective in use in the agricultural sector of Central Asia in general and the Jalal-Abad region in particular.

Table 3. Green technologies of the agro-industrial complex, effective when applied in the agricultural complex of Central Asia and the Jalal-Abad region

Technology	Essence	Advantages of the application	Prospect of implementation in the region
Remote sensing of the area	Use of unmanned aerial vehicles to monitor the condition of the soil in a given area of agricultural work	Ability to calculate various soil and vegetation indices based on the light reflected by plants and soils, which significantly expands the possibilities of determining quantitative and qualitative indicators of various agroecosystems	Conducting scientific research to determine the dynamics of changes in soil conditions in the region and the feasibility of planting certain types of crops and monitoring environmental processes
Comprehensive pest control	Control of agricultural pests through natural methods, provided that minimal damage is caused to the environment	It allows effectively resisting pests of agricultural crops, without harming agricultural ecosystems	In the agro-industrial sector of the Jalal-Abad region and in Central Asia as a whole, a comprehensive strategy for improving the quality of crop protection and harvest has been developed
Vertical farming	Technological process in the agricultural industry in which the cultivation and production of food takes place on surfaces with a vertical slope	It helps to make much better use of space, with an increase in the number of cultivated crops that can be placed on a unit area	Expanding the possibilities of farming in the region and reducing the amount of soil and irrigation water used for crops. Year-round harvesting provides an increase in the yield of traditional crops by several dozen times
Anti-erosion tillage	Tillage by means of general (ploughing, harrowing, cultivation) and special (slitting, grooving, furrowing) techniques, to provide protection against erosion	Provides the maximum possible absorption of moisture from precipitation into the soil, prevents moisture loss by evaporation, promotes safe drainage of water in areas with excessive moisture in the soil layer	Improvement of the quality of soil treatment, which ensures the preservation of their fertile properties for as long as possible. This is especially true for meadow-steppe soils of the Jalal-Abad region, characterised by increased salinity and carbonate content, and a developed humus horizon
Organic farming	Technology for maintaining soil and ecosystem health based on ecological processes, diversity of biological species and cycles specific to the realities of a particular region and area, rather than on the involvement of resources that cannot be renewed	The possibility of providing medium- and long-term effects on the agro- and ecosystem, food production in a balanced ecological situation, preventing depletion of soil fertility, eliminating problems with pests of agricultural crops	It attracts additional attention of investors due to the discovery of opportunities for the rational use of soils, in conditions of their premature depletion and loss of fertile properties
Biological technologies	Technologies of cryopreservation of seeds, their artificial production, somatic embryogenesis, and other forms of tissue or cell cultures	The possibility of obtaining plant varieties with increased resistance to pests, increasing the productivity of agricultural crops and their feed value	Development and implementation of additional sources of raw materials for secondary and reproducible resources, including agricultural waste, their subsequent use as feed preparations, organic fertilisers. Significant increase in crop yields

Source: compiled by the authors based on T. de Ponti et al. (2022) and E. Bottani et al. (2022)

According to the analytical data presented in Table 3, the use of green technologies in the agro-industrial

complex of the Jalal-Abad district and the Central Asian region as a whole carries numerous advantage

that determine the prospects for their subsequent use in the practice of agricultural enterprises. In particular, the prospects for the introduction of vertical farming technologies lie in the possibility of reducing the area of soil used for crops and water for irrigation. In addition, the use of this kind of technology allows harvesting crops all year round, which helps to increase the yield of traditional crops by several dozen times (Rodrigues *et al.*, 2024). The use of organic farming technologies and biotechnologies for the safe processing of industrial waste allows creating effective fertilisers, which significantly increases soil fertility and their useful life for harvesting (Mandal *et al.*, 2021).

In the Kyrgyz Republic, as in the whole world, there are a number of problematic situations that need to be addressed related to population growth, the influence of climatic factors and the negative impact of the pandemic, which generally leads to increased interest in ensuring healthy nutrition, and environmental protection. In this context, the use of a wide range of green technologies, in particular: organic farming, biotechnologies, etc., provides agricultural enterprises implementing them with competitive environmental advantages compared to other methods of agricultural production (Strapchuk & Mykolenko, 2022;

Dimitrijević *et al.*, 2024). This is especially important in the situation that has developed by mid-2024, when the development of efficient agriculture in terms of resource consumption has become one of the key areas of development even for a number of leading world powers with significant reserves of natural resources (Honcharuk *et al.*, 2024). The efficiency of using natural resources should be considered one of the main priorities of a large number of UN member countries, while green environmental technologies can become the most important means of implementing new innovative solutions designed to effectively solve the tasks of increasing resource efficiency, dematerialising production and consumption, and attracting a number of auxiliary sources of value formation (Burdina & Priss, 2016; Dong *et al.*, 2022).

The role of green technologies in the context of increasing the competitiveness of innovative development also lies in the prospects for solving a wide range of problems of agro-industrial enterprises through the use of these technological solutions in combination with digital technologies (Saparova, 2024). Table 4 presents the main problems of the agro-industrial complex of Central Asia, successfully solved by the practical application of this complex of technological solutions.

Table 4. Problems of the agro-industrial complex of Central Asia, successfully solved through the use of green and digital technologies

Problems	Effect of the introduction of technological solutions
Climate risks	Reduction of climate risks through the use of digital sensors to monitor the response to climate change in the soil structure, along with the use of vertical farming technologies, monitoring and control of the movement and condition of pets, and the use of other, more advanced technologies and systems
The use of outdated machinery in agricultural work	Use of digital systems and equipment with a digital interface that provide full control of the entire cycle of the process of using green technologies, with timely detection of equipment malfunctions, reduction of repair time and replacement of necessary parts, while processing significant amounts of data in a short time
Insufficient diversification of agricultural products	Expanding economic activity and increasing its contribution to the social and economic development of rural areas based on equal opportunities for all participants in the agricultural production process, through the effective use of innovative green and digital technologies
Lack of qualified personnel in agro-industrial enterprises	Use of digital databases and integrated training systems to reduce the training time of specialists in the field of digital and green technologies in agriculture
Problems of supply of manufactured goods to domestic and foreign markets	Use of a digital online portal will facilitate the timely provision of information needed by rural producers to reduce transaction costs and activate the supply chains of agricultural products to the end consumer
Low productivity of manual labour with the practical implementation of green technologies	Introduction of digital technologies in all production processes involving the introduction of green technologies will generally lead to an increase in the productivity of employees of agricultural enterprises, facilitate mechanical processes with their replacement by automatic processes, which in the future will enable reporting on the results of these processes

Source: compiled by the authors based on Z. Abulova *et al.* (2023)

As follows from the information provided in Table 4, the combination of green and digital technologies in the practice of agro-industrial enterprises in Central Asia causes these enterprises to have significant competitive advantages. This should be explained by the fact that such a model of interaction involves providing agricultural enterprises with the basic principles

of sustainable development for a considerable time, by attracting investment funds necessary for the introduction of a combination of these technologies. In addition, it provides support for the implementation of sustainable development objectives related to environmental protection, conservation, and enhancement of natural resources, a low-carbon economy, and social

responsibility (Du, 2024). This is especially relevant in the 21st century, in conditions of constantly increasing use of natural resources, and anthropogenic pollution of the area, which together necessitated the search for alternative technological solutions that allow maintaining the production of agricultural products at the proper level and preserving the ecological diversity of the environment (Gupte *et al.*, 2023). The final effect of the implementation of green technologies in the practice of agricultural farms in Central Asia largely determines the prospects for the establishment of these farms on the principles of an innovative economy as a whole, and the availability of opportunities to increase the competitiveness of the entire agricultural sector in the long term.

DISCUSSION

During this scientific study, the results were obtained, indicating the presence of significant advantages of using green technologies in the practice of agricultural farms in the Jalal-Abad region in January-August 2024. Their use contributes to an increase in crop yields, soil fertility and, in general, has a positive impact on the prospects for innovative development of modern agricultural enterprises of the Kyrgyz Republic. R.D. Raut *et al.* (2019) in a joint study aimed at investigating parameters for tracking the effectiveness of the implementation of green management practices for agricultural companies, note that the use of green technologies in the management of enterprises in the agricultural sector of the economy minimises the impact of the supply chain on the external environment, while increasing its economic efficiency. According to the researchers, various aspects of the productivity of agricultural enterprises are important from the standpoint of optimising resource consumption, and the practical implementation of the concepts of sustainable development of a single organisation. The opinion of researchers is fully confirmed by the results that were revealed during this study due to the fact that the issues of optimising the consumption of resources of a single agricultural company are essential from the standpoint of increasing its productivity, provided that the technologies in question are introduced into its activities.

The topic of the introduction of green technologies into the activities of agricultural producers to increase the bioconversion of agricultural waste was considered by B. Singh and A.S. Jana (2023). Researchers pointed to the fact that the cultivation of agricultural crops is inevitably accompanied by a large amount of solid waste, the dumping of which in landfills causes numerous environmental problems. To manage this process, a special approach is needed, based on the use of green technologies aimed at solving issues of waste disposal and recycling, without harming the environment (Myronycheva *et al.*, 2017). According to the researchers, this will help to increase the competitiveness of innovative development of rural agricultural regions in which

technologies of this kind have found their application. The opinion expressed coincides with the results obtained in this study, since the methods of applying biological technologies and organic farming (including the use of fertilisers obtained during the processing of industrial waste) in the agricultural sector allow farms to obtain a higher yield per unit area, which distinguishes them from farms that do not use such technologies.

T. Marinchenko (2020) considered a number of issues related to the construction of a methodology for expert assessment and selection of innovative projects in the agricultural business and the organisation of agricultural enterprises. According to the researcher, an integral part of innovation activity in the field of application of green technologies of the agro-industrial complex is the selection of innovative projects and the system of evaluation of the innovativeness of the proposed solutions based on it. However, there are difficulties in measuring the quality indicators of innovative projects being implemented and their true effectiveness when used in the activities of modern agricultural companies (Stepanenko *et al.*, 2023). The opinion expressed is controversial on the grounds that the innovativeness of the proposed solutions can often be fully assessed only after a certain time after a practical result has been obtained from the application of a particular project.

The topic of the introduction of green technologies for the production of environmentally friendly products in agriculture has been considered by S. Bhadra *et al.* (2022). The researchers note that the use of green technologies in agriculture, such as plant-microbial fuel cells to produce environmentally friendly bioelectricity and wastewater treatment, helps to reduce the amount of waste and allows them to be effectively disposed of. According to researchers, the use of such technological innovations is necessary to increase the competitiveness of agricultural enterprises using them in their daily activities. The opinion expressed is confirmed by the results obtained in this study, since the effective disposal of industrial waste through organic farming methods and biological technologies increases soil fertility, which, in combination with vertical farming methods, allows increasing the volume of harvesting per unit area, which, in turn, increases the competitive stability and investment attractiveness of farms using these technologies.

A similar topic is raised in the paper by R. Sharma (2024), aimed at studying the problems of converting agro-industrial waste into energy. The researcher makes a statement that the use of innovative green technologies to ensure environmentally friendly recycling of waste from agricultural enterprises has an effective social and economic impact. This allows forming a closed-loop model for the entire agricultural industry, in which waste products, passing through an intermediate phase, are again converted into material for subsequent use. The researcher's conclusions are confirmed by the results obtained in this study due to the fact that

the use of green waste recycling technologies in the practice of agricultural enterprises contributes to increasing soil fertility and productivity.

The issues of practical application of green technologies in solving problematic issues of enterprises in the agricultural sector of the economy for the production of composite materials from waste were discussed by D. Zindani *et al.* (2021). Researchers pointed to the fact that numerous environmental problems associated with the incineration of agricultural waste can be successfully solved through the use of innovative green technologies based on the production of green composites from agricultural waste. They are produced specifically for the development of environmentally friendly products, which allows solving a number of problems in this sector and increasing the competitiveness of enterprises that introduce such production. The conclusions of the researchers generally correspond to the results that were obtained in this study, while it should be noted that the issues of increasing the competitiveness of agricultural enterprises implementing green technologies require more detailed consideration, since competitiveness in the context of the development of the modern agricultural sector depends on a number of additional factors.

D. De *et al.* (2021) in a joint study aimed at investigating a number of problematic aspects of creating a strategic platform for the environmentally friendly processing of agricultural waste, note that the production of biologically based composite materials reinforced with cellulose has become an effective biologically sustainable alternative to high-quality functional polymer materials to replace the currently dominant plastics based on oil. However, according to researchers, the development of an inexpensive carbon-neutral strategy for the separation of cellulose particles from lignocellulose waste residues to simultaneously reduce the amount of solid waste is an innovative solution that in the future can provide opportunities for innovative development of agricultural companies applying this kind of technological innovations. The opinion expressed corresponds to the results obtained in this study, since the use of a number of biological technologies in the practice of agricultural producers contributes to increasing the stability and yield of crops, due to higher quality of soil treatment due to effective waste processing.

U. Sarma *et al.* (2024) examined a wide range of issues related to the use of green technologies to produce relatively clean wastewater. The researchers express the opinion that the practical implementation of technological solutions of this kind will contribute to solving the problems of the water crisis in cities and industrial enterprises. After the conducted research, the conclusion is presented that the prospects for using green technologies to increase the level of environmental sustainability of agricultural enterprises and entire cities are quite wide, while their use contributes to an increase

in the overall level of environmental protection, which is of fundamental importance from the standpoint of the development of a green economy. This conclusion needs additional verification, since studies using statistical data are needed to confirm the effectiveness of green technologies in environmental protection

A. Jahan *et al.* (2023) discussed the use of innovative green technologies for the manufacture of coatings obtained from secondary products of agricultural enterprises. A team of researchers expresses the opinion that such green technologies are very effective for combating metal corrosion of agricultural machinery, while extending the life of its trouble-free operation. On this basis, it is concluded that the use of green technologies in the sector under consideration has significant prospects, since it allows optimising the activities of agricultural companies using them, providing them with additional prospects for innovative development and tangible competitive advantages. The presented conclusion is confirmed by the results of the conducted research, since they clearly demonstrate the fact of the effectiveness of the use of the technologies in question in the practice of a number of farms in the Jalal-Abad region.

CONCLUSIONS

As a result of the conducted research, it was found that the practical application of green technologies of the agricultural sector in the activities of farms in the Jalal-Abad region of Kyrgyzstan contributed to a significant increase in the volume of production of these farms in 2024 compared with 2023. In the agro-industrial farms of the region in question, in 2024, a number of green technologies aimed at increasing soil fertility and yield, producing fertilisers from agricultural waste, increasing the effectiveness of pest control in agriculture, and finding more optimal ways to sow suitable areas of the area and year-round harvesting from the chosen crop for this purpose showed significant practical effectiveness the terrain.

Improving the competitiveness of the innovative development of the Jalal-Abad region of Kyrgyzstan and Central Asia as a whole through the introduction of green technologies in the sector of the economy taken for research lies in the availability of practical experience for agricultural enterprises using these technologies to effectively address issues of agricultural production. Thus, the increase in the volume of harvesting of cereals, potatoes, vegetables, melons, and fruit and berry crops in a number of districts of the Jalal-Abad region in 2024 compared to 2023 due to the use of a number of green technologies in the practice of agricultural farms emphasises the innovation and effectiveness of these technologies, and opens up significant prospects for their further use. This is especially relevant in the conditions of the Kyrgyz Republic, given the significant role of the agro-industrial sector in the

country's economy, due to the predominance of mountainous terrain and the concentration of a significant part of the population in rural areas.

The limitations of this study are caused by difficulties in assessing the final effect of the use of green technologies in the practice of individual agricultural farms and related problems of assessing their real innovativeness on the scale of individual regions and Central Asia as a whole. The practical importance and the need for further research in the framework of the

subject matter are conditioned by the increasing role and importance of green technologies in improving the competitiveness of innovative development in Central Asia and the Kyrgyz Republic, as an integral part of it.

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CONFLICT OF INTEREST

None.

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Анотація. Метою даної науково-дослідницької статті виступав аналіз переваг застосування зелених технологій, як інноваційного засобу підвищення ринкової стійкості сільськогосподарських компаній центрально-азійського регіону. Суть методологічного підходу в представленому дослідженні становило поєднання теоретичних методів аналізу і синтезу з емпіричним дослідженням питань застосування зелених технологій у практиці господарств аграрного сектора Джалал-Абадської області Киргизстану. Під час виконання наукового дослідження було отримано результати, що відображають динаміку зміни обсягів урожайності ключових сільськогосподарських культур протягом часових проміжків січень-серпень 2023-го та 2024-го років. Були отримані дані про зелені технології сфери сільського господарства, які успішно застосовуються в Киргизькій Республіці, і особливо в Джалал-Абадській області, що дають змогу підвищити врожайність сільськогосподарських культур, збільшити обсяги виробництва продуктом тваринництва. Висвітлено роль застосовуваних у сільському господарстві зелених технологій, як ключового елемента підвищення конкурентоспроможності аграрних компаній та інноваційного розвитку Центральної Азії загалом, оскільки було представлено реальні перспективи впровадження цих технологічних рішень на прикладі аграрних господарств Джалал-Абадської області. Ці перспективи, зокрема, полягають у можливості поліпшення параметрів родючості ґрунтів за рахунок застосування біологічних технологій перероблення відходів сільськогосподарського виробництва для розроблення більш якісних добрив, пошуку ділянок ґрунтів для оптимального висаджування тих чи інших видів сільськогосподарських культур за рахунок застосування методів дистанційного зондування місцевості, удосконалення процесу обробітку ґрунтового шару за рахунок застосування методу протиерозійного обробітку ґрунту, а також багатьох інших аспектів

Ключові слова: сільське господарство; промисловість; передові рішення; екологія; регіональне виробництво; впровадження удосконалень
