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Analysis of innovation potential of regional agroclusters

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Abstract. The study analysed the key resources and conditions affecting the development of innovation activities in regional agroclusters. The study conducted a comprehensive analysis of the innovation potential of agroclusters, including the assessment of key factors such as human resources, research base, financial support, and technological infrastructure, using SWOT-analysis, index method and experts. The analysis revealed that the level of innovation potential of regional agroclusters was determined by the degree of interaction between enterprises, scientific institutions, and government structures. Funding of agro-industrial cluster in Kazakhstan was USD 2.5 bn, of which

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USD 0.8 bn was allocated for innovation, while in the Netherlands, USA (California and Iowa) these indicators were much greater, reaching USD 10-15 bn with innovation costs within USD 2.8-6.5 bn. For example, in Kazakhstan, a stable growth of agro-industrial complex by 3.6% per year has been observed since 2010, which contributed to an increase in labour productivity to USD 6.6 thsd per person – 30% greater than the indicators of Ukrainian farmers. The study found that the availability of specialised infrastructure (agrotechnoparks, technology transfer centres) contributed to accelerated innovation. The study also confirmed that the key barriers to innovative development of agroclusters included insufficient research and development funding, lack of qualified personnel, and weak cooperation between participants. For instance, the use of precision farming and artificial intelligence technologies can increase crop yields by 20% and reduce water use by 30%. In regions with active state support and access to investment, such as Kazakhstan, an increase in the number of start-ups and venture capital investments was observed. Based on the analysis, recommendations for developing the innovation potential of agroclusters were proposed, including the creation of incentive support measures, the development of educational programmes, and the introduction of digital platforms for technology exchange. The findings obtained can be used to develop strategies to support and stimulate innovation activity in regional agroclusters, which contributes to improving their competitiveness and efficiency

Keywords: digitalisation; state support; cooperation; investment; technology; infrastructure

INTRODUCTION

In the context of globalisation and rapid technological advancement, agriculture faces new challenges that require finding effective solutions to improve the productivity and sustainability of the agricultural sector. In this regard, regional agroclusters are becoming crucial centres of innovative development, bringing together the efforts of agricultural producers, scientific institutions, technological and educational organisations. They play a key role in the introduction of modern technologies such as digitalisation, agrotechnologies, and biotechnologies, contributing to the competitiveness of the agro-industrial complex. Analysing the innovation potential of regional agroclusters allows identifying the strengths and weaknesses of existing models, as well as determining the factors affecting the success of their development. A prominent aspect is the integration of scientific research and technology into real production processes, which requires close interaction between multiple cluster participants. A systematic approach to assessing the innovation activity of agroclusters opens opportunities for the creation of effective development strategies, improvement of the investment climate, and stimulation of sustainable growth of agrarian regions.

The problem of assessing the innovation potential of regional agroclusters lies in the need for a comprehensive approach that would include analysing the interaction of participants, infrastructure development, and the introduction of new technologies. K. Sharma and S.K. Shivandu (2024) focused on the value of digitalisation in agro-production, stressing that technologies such as Internet of Things (IoT) and Artificial Intelligence (AI) enabled marked improvements in agricultural productivity and competitiveness. The researchers also argued that digital transformation was a key factor for successful development of agroclusters in the face of global change. V. Agarwal *et al.* (2023) investigated the role of public-private partnerships in the agricultural sector, emphasising that government support helped to stimulate the adoption of the latest technologies and innovative solutions. Their study showed how tax incentives and subsidies could be effective tools to attract investment in the agro-industry. M. Aydoğan *et al.* (2021) stressed the significance of cooperation between scientific institutions and agricultural producers, emphasising that such integration contributed to accelerated innovation and development of innovative technologies. The researchers believed that successful examples of collaboration considerably improved the production performance of agroclusters. L. Bjerke and S. Johansson (2022) investigated the relationship between human resource quality and the innovation capacity of agroclusters, arguing that the training of skilled agricultural professionals was a crucial element for the adoption of the latest technologies. Their study emphasised the need for a close link between educational institutions and agro-producers to build talent pools.

D. Akkaya *et al.* (2020) analysed the influence of government policies on the innovative development of the agribusiness sector, focusing on the significance of subsidies and tax incentives to create favourable conditions for business. The researchers also emphasised that such measures stimulated entrepreneurial activity and ensured the inflow of investments into the agro-industry. E. Mugoni *et al.* (2023) examined the value of logistics and marketing in the success of agroclusters, noting that efficient transport and marketing systems for agricultural products played a key role in the development of the industry. The researchers argued that without an established infrastructure, innovation in the agribusiness sector could not fulfil its full potential. M. Yazdani *et al.* (2021) investigated the risks associated with the adoption of the latest technologies in

agribusiness and highlighted the significance of developing risk management strategies to minimise potential losses. The researchers emphasised that effective risk diagnosis and forecasting helped to increase the resilience of agroclusters to external and internal threats.

C.-I. Coman *et al.* (2024) investigated the prospects of adopting environmentally sustainable agro-technologies, emphasising their value for the long-term development of agroclusters. The study also analysed the effects of clusters in managing technological challenges and achieving sustainability of agri-food systems globally, highlighting the significance of cluster structure in addressing the world's environmental and economic challenges. G.A.B. Aggrey *et al.* (2022) addressed the need for SMEs to integrate into innovation processes, which they found to improve the growth dynamics of agroclusters. Their study emphasised that such enterprises could play a key role in the adoption of innovative technologies, providing flexibility and adaptability to the agribusiness sector. Despite significant contributions to the study of the problem, there is a series of gaps that require further investigation. Specifically, insufficient attention has been paid to a comprehensive analysis of the factors affecting the sustainability of innovation potential of agroclusters under conditions of market uncertainty and variability. Further research is required on the models of interaction between large and small enterprises within agroclusters, as well as the development of recommendations for optimising state support mechanisms at the regional level.

The purpose of the present study was to identify the factors that determine the innovation potential of agroclusters, as well as to analyse the existing methods of assessment and ways to develop this potential.

MATERIALS AND METHODS

The study comprehensively analysed the innovation potential of agroclusters, covering both theoretical foundations and practical methods of assessment. An essential task was to identify the key factors affecting the innovative development of agroclusters, as well as to highlight the best practices and successful examples of agrarian regions where innovative technologies are actively implemented. Within the theoretical framework of the study, the key components comprising the innovation potential of an agrocluster were considered. One of the key factors was the availability of human resources, including qualified specialists, level of education in the field of agrarian technologies, and competences in the field of entrepreneurship. The research base, including universities and agrarian institutes, also played a major role by ensuring that the latest technologies were tested in real-life conditions through experimental farms. Furthermore, attention was paid to financial support, including government subsidies and private investment as a catalyst for the implementation of innovative solutions.

The next stage of the study concerned the methodology for assessing the innovation potential of agroclusters. For this, various methods were employed, including SWOT analysis, which helped to identify the strengths and weaknesses of the agrocluster, as well as to assess opportunities and threats to its development. This analysis considered indicators such as gross regional product (GRP), farm profitability, and employment growth. SWOT analysis was used to identify the strengths, weaknesses, opportunities, and threats associated with innovation in the agricultural sector. This enabled the development of strategies to improve the economic performance of the region based on the data (Mastac & Vancea, 2024). The index method helped to quantify the level of innovation activity, through the number of patents and the degree of digitalisation. To comprehensively assess the innovation potential of agricultural clusters, an integral innovation index was constructed. This index included several separate indices: financial (share of investment in innovation, % of GRP), infrastructural (number of technoparks and technology transfer centres), human resources (share of STEM personnel), and digital (number of digital solutions per 100 agrarian enterprises) based on the data (Musayeva, 2024). This method was aimed at a systematic assessment of the state of innovation infrastructure and human resource potential in the agricultural sector. For this, the formula for calculating the integral innovation index of agrocluster was used (Equation 1):

$$I_{agrocluster} = w_1 \times I_{financial} + w_2 \times \\ \times I_{infrastructural} + w_3 \times I_{personnel} + w_4 \times I_{digital}, \quad (1)$$

where w_1, w_2, w_3, w_4 are weights assigned to each of the indices. These weights reflect the relative significance of each index to overall innovation activity. For example, if infrastructure is more significant than the human resources index, the infrastructure index may be given a higher weighting. $I_{financial}$ is the index reflecting the share of investment in innovation in the agricultural sector. $I_{infrastructural}$ is the index reflecting the level of development of infrastructure for innovation, such as technoparks or technology transfer centres. $I_{personnel}$ is the index reflecting the share of highly qualified personnel (e.g., STEM personnel) in the agricultural sector. $I_{digital}$ is the index reflecting the degree of digitalisation of the agricultural sector (e.g., number of digital solutions per 100 agricultural enterprises).

The cost-effectiveness method was employed to assess the feasibility of introducing innovative solutions such as digitalisation and agrodrones. It consisted of comparing the costs of implementing these technologies with the resulting economic benefits, such as increased yields, reduced losses, and increased value added. The method was employed to understand how effective investments in innovations can be in terms of their economic and financial returns based on the data

(Taishykov *et al.,* 2023). One of the key aspects of the study was to identify the factors influencing the innovation potential of agroclusters. Geographical location and climatic conditions, as well as the availability of natural resources, played a prominent role in determining the potential for the adoption of innovative technologies. The specifics of agriculture in each region required an individual approach to the use of technologies. Furthermore, the level of cooperation between cluster members, including partnerships between producers, research institutions, and processing enterprises, was a significant factor. Government support and infrastructure support, such as the availability of logistics centres and digital platforms, played a crucial role in the successful implementation of innovative projects.

The study also included examples of successful agroclusters with high innovation potential, such as the Kazakhstan agrocluster (Ryskeldi *et al.,* 2024), the Dutch agrocluster Foodvalley (n.d.), and the US (California) agroclusters (Love, 2024) and IOWA (2023). These examples demonstrated how the introduction of precision farming technologies, agricultural automation, and the use of biotechnology can considerably improve the productivity and sustainability of agricultural production. Kazakhstan has actively developed its agribusiness sector through digitalisation and innovative approaches, including the use of IoT and drones. In the Netherlands, pronounced levels of automation and sustainable agriculture served as an example of how innovation can reduce costs and improve sustainability. Agroclusters in the US have also used biotechnology and artificial intelligence to predict crop yields, enabling optimisation of agricultural processes.

RESULTS

The innovation potential of agroclusters is a set of factors and conditions that determine the ability of agrarian associations to introduce innovative technologies, improve agricultural efficiency, and adapt to changing conditions. Modern agriculture, facing the challenges of climate change, growing demands for food security, and global competition, requires active use of innovations. A prominent aspect in this process is to identify and analyse the key components that determine the innovation potential of agroclusters. These include human resources, research and development base, financial support, technological infrastructure, and institutional environment. The introduction of innovations in the agro-industrial complex (AIC) positively affects labour productivity and the share of gross regional product associated with this sector. For example, Kazakhstan experienced steady growth in agribusiness at 3.6% per annum since 2010, which contributed to an increase in labour productivity to USD 6.6 thsd per person – 30% greater than the performance of Ukrainian farmers. Analogous trends are observed in other regions, where a high innovation index correlates with higher labour productivity and increased contribution of agribusiness to the economy. These data emphasise the value of innovation for the sustainable development of the agricultural sector and the economy overall (Kazakhstan and Ukraine, n.d.).

The key component of the innovation potential of an agrocluster is the availability of qualified specialists who can develop, adapt, and implement the latest technologies in agrarian production. The level of education in the field of agrarian and innovative technologies plays a key role in the training of personnel capable of meeting the challenges faced by agroclusters. Specialists with a prominent level of education, including engineers, agronomists, biotechnologists, and information technology (IT) specialists, are needed to develop and implement innovative solutions such as precision farming systems, biotechnology, and process automation. Furthermore, competences in the field of innovative entrepreneurship are significant, which allow effectively transforming scientific developments into successful commercial projects. The availability of such specialists facilitates the creation of innovative start-ups, improvement of business processes, and implementation of advanced technologies.

The research base, which includes universities, agricultural research institutes and experimental farms, represents the basis for the development of innovative technologies and solutions. Universities and research institutions play a key role in training and research to address agricultural challenges such as increasing yields, improving product quality and climate resilience. Experimental farms, as a vital part of the research infrastructure, allow testing the latest technologies and putting them into practice. These farms form the link between scientific development and industrial implementation, where research results directly affect the efficiency of agricultural production. Assessment of the payback of innovative solutions is a key tool for analysing the effectiveness of investments in innovative technologies in agriculture. For example, the introduction of digital farm management systems such as AGRIVI enables farmers to increase profitability by 50-100% as early as in the first two years of use. Additionally, the use of precision farming and artificial intelligence technologies can increase crop yields by 20% while reducing water use by 30%. These examples demonstrate that investments in digital technologies not only pay for themselves in a short time but also contribute to major improvements in the efficiency and sustainability of agricultural production (Zulj, n.d.).

One of the crucial factors determining the innovation potential of agroclusters is financial support. The development of innovation in agro-production requires extensive investment from both the government and private investors. Government subsidies, grants, and programmes to support innovative projects are an incentive for the introduction of innovative technologies

and improvement of production processes. Private and venture capital investments also play a valuable role in stimulating innovation activity. Agricultural technology-focused companies and funds help finance start-ups and projects aimed at introducing innovations such as new biotechnologies, production automation, and improving agricultural resilience to environmental changes. Technology infrastructure is the set of facilities and services needed to implement and disseminate innovations. Agrotechnoparks and technology transfer centres are the basis for creating, testing, and implementing the latest agricultural solutions. These infrastructural elements provide access to high-tech equipment, resources for the development of innovative technologies and opportunities for the exchange of knowledge and experience between scientists, entrepreneurs, and producers. The development of digital platforms for agribusiness also forms an integral part of the technological infrastructure. The digitalisation of agribusiness allows for better management of agricultural processes, improved resource efficiency, and the adoption of the latest technologies such as yield monitoring and forecasting systems, the use of drones, and satellite data to assess crop health.

The institutional environment includes the regulatory framework governing innovation in the agricultural sector, as well as programmes and initiatives to support and promote agro-innovation. Legal and institutional frameworks play a key role in creating favourable conditions for the adoption of innovative technologies and business models. Regulations governing intellectual property protection, subsidies, and tax support for innovative projects provide stability and predictability for participants in agroclusters. Government support programmes, such as research grants, subsidies for the introduction of the latest technologies or training programmes for specialists, are key tools to stimulate innovation in the agricultural sector. Furthermore, the integration of agroclusters into international networks and participation in international projects allow sharing experience and adopting best practices.

Overall, the innovation potential of agroclusters depends on many interrelated factors. Human resources, research and development base, financial support, technological infrastructure, and institutional environment create conditions for the development of innovations and increase the competitiveness of agricultural regions. The development of these components contributes to improving the quality of agricultural products, enhancing the sustainability of the agricultural sector, and addressing global challenges such as climate change and food security. Innovation plays a major role in increasing the profitability of agricultural enterprises. As the level of innovation increases, such enterprises become more efficient and competitive. The introduction of innovative technologies can considerably improve production processes, optimise resources, and increase product quality, which ultimately leads to higher profits. Companies that actively innovate often find new markets and ways to increase profitability, which allows them to compete in the face of globalisation and rapidly changing market conditions (Table 1).

***Table 1**. Profitability of agricultural enterprises depending on innovation potential*

Level of innovation activity	Profitability (%)
Low	5
Medium	12
High	20

***Source:** compiled by the authors of this study based on R. Kosfeld and T. Mitze (2023)*

Clustering also has a noticeable impact on the economic performance of regions. Regions with a prominent degree of clustering have greater growth in indicators such as exports, labour productivity, and wages. Clustering facilitates the exchange of expertise and technology between companies, increases access to innovation, and improves infrastructure. This leads to increased efficiency of the entire region, incentivising both small and large businesses. Moreover, the development of clusters helps to optimise processes and reduce costs, which improves the economic situation in the region (Table 2).

***Table 2**. Dynamics of exports, productivity, and wages in regions with varying clustering levels*

Level of clustering	Export growth (%)	Productivity growth (%)	Wage growth (%)
Low	3	4	2
Medium	10	12	8
High	18	25	15

***Source:** compiled by the authors of this study based on S. Andros et al. (2021)*

Assessment of the innovation potential of agroclusters plays a key role in designing strategies for their further development. This approach allows identifying both strengths and weaknesses of an agrocluster, as

well as understanding what opportunities and threats may affect its ability to introduce innovative technologies. There are several techniques that can be used for a comprehensive assessment of the innovation potential of an agrocluster, among which the most popular are SWOT analysis, index method, expert questionnaire survey, and socio-economic analysis.

One of the most widespread assessment methods is SWOT-analysis, which enables a systematic assessment of internal and external factors affecting the innovation potential of an agrocluster. This analysis considers strengths and weaknesses, as well as opportunities and threats to innovation development. For instance, strengths may be the availability of highly qualified specialists and a developed research base, which contribute to the introduction of innovative technologies. Weaknesses may include a lack of financial resources or outdated infrastructure. Opportunities for growth may be related to the development of new markets or the introduction of environmentally sustainable solutions, while threats may include economic instability or fierce competition from other regions. A SWOT analysis identifies areas for improvement and optimisation of the cluster's innovation activities (Arion *et al.,* 2023). SWOT analysis by economic indicators, such as GRP, household income, and employment growth, allows identifying key factors that influence the development of a region or industry (Table 3).

***Table 3**. SWOT analysis for economic indicators*

Strengths	**Weaknesses**
High level of investment in key sectors (positive impact on GRP)	Low farm profitability, limited access to finance
Growing digitalisation index, which contributes to improved productivity	Lack of highly qualified personnel, which limits innovation processes
Increased cooperation between enterprises, leading to increased employment	Low diversification of the economy, dependence on several industries
Stimulating small and medium-sized businesses, increasing the number of jobs	Infrastructure problems hampering the development of some industries
Opportunities	**Threats**
Development of innovative technological and scientific solutions that can increase farm profitability	Economic instability, possible external shocks that may reduce GRP
Attraction of foreign investment in innovative industries	Obsolescence of production facilities and lack of technological upgrades
Improvement of the education and training system to raise the skills of the workforce	Decrease in employment due to automation and digitalisation of processes
Increased cooperation between regions, which contributes to economic growth	Shortage of natural resources, which may complicate further growth of the economy in the long term

***Source:** compiled by the authors of this study based on L. Mastac and D.P.C. Vancea (2024)*

The strengths include the pronounced level of investment in key sectors, which positively influences GRP growth and economic development in the region. A significant contribution to the improvement of economic performance is also made by the growth of the digitalisation index, which increases labour productivity and reduces costs, leading to increased farm profitability. A prominent factor is cooperation between enterprises, which contributes to employment growth and improved economic sustainability. Furthermore, the stimulation of SMEs creates new jobs, which also contributes to employment growth. However, there is a series of weaknesses. For example, the low profitability of farms caused by underfunding or the use of obsolete technologies limits their potential and does not contribute to GRP growth. Lack of highly skilled labour constrains innovative development, while infrastructure problems hinder the development of certain industries, slowing overall economic growth. Some regions also have poorly diversified economies, making them vulnerable to external shocks.

At the same time, there are opportunities that can contribute to improving the situation. The development of innovative technological solutions and scientific advancement can markedly increase the profitability of farms and make a valuable contribution to GRP growth. Attracting foreign investment in innovative sectors will modernise production, create additional jobs, and accelerate economic growth. Improvement of the education and training system also helps to improve the skills of the labour force, which will positively influence labour productivity and economic activity. However, threats such as economic instability or global crises may arise in the long term, which could negatively affect investment and GRP growth. Furthermore, automation and digitalisation of processes, despite their positive effects on efficiency, may lead to a decrease in employment, especially in conventional industries. There may also be a shortage of natural resources, which will limit further economic development, especially in sectors that are highly dependent on them. This SWOT analysis helps to understand which aspects need attention and which factors may have the greatest impact on the economic development of the region.

Another significant tool is the index method, which involves the use of quantitative indicators to assess the

level of innovation activity of an agrocluster. Among these indicators can be the number of patents and technologies, the degree of digitalisation, the amount of investment in research and development. For instance, a great number of patents may indicate a robust level of R&D activity, while the adoption of digital technologies such as precision farming systems may indicate a strong level of technological maturity. The index method collects data on the current state of innovation and systematises it for further analysis (Bernard *et al.,* 2023). To build an integral innovation index of Kazakhstan's agrocluster, it is necessary to collect data on key indicators such as the share of investment in innovation, the number of technology parks and technology transfer centres, the share of STEM personnel in the agricultural sector, and the number of digital solutions per 100 agrarian enterprises. Each of these indices should be standardised, bringing the values to a common scale from 0 to 1 so that they can be compared and integrated into an overall indicator.

Data for Kazakhstan can be used as an example (Musayeva, 2024). For instance, the share of investment in innovation was 1.5% of GRP, which with a maximum value of 5% gives a standardised value of 0.30. The number of technoparks in Kazakhstan is 4, with a maximum of 10 technoparks, this gives a value of 0.40. The share of STEM personnel in the agricultural sector is 12%, which at a maximum of 30% also gives an index of 0.40. Finally, the number of digital solutions per 100 agricultural enterprises is 25, which with a maximum of 50 solutions gives an index of 0.50. Once all the indices are standardised, it is possible to assign them weights that reflect their significance for innovation activity. In this example, all indices have the same weighting of 0.25. Based on these data, the integral innovation index of the agrocluster is calculated as follows:

$$I_{agrocluster} = 0.25 \times 0.30 + 0.25 \times 0.40 + 0.25 \times 0.40 + 0.25 \times 0.50 = 0.40.$$

This means that innovation activity in Kazakhstan's agricultural sector is at an average level, with potential for improvement in the areas of investment, human resources, and digitalisation. Thus, the integral innovation index allows assessing the current level of innovation activity in the agricultural sector of Kazakhstan and identify key areas for further development. The Cost-Effectiveness Analysis (CEA) method is employed to assess the costs of implementing innovative solutions and their corresponding economic benefits. This method compares the costs of technologies such as digitalisation or agrodrones with the results they bring, e.g., in the form of increased yields, reduced losses, or increased value added. The essence of the method is to assess how effective a particular technology investment is in terms of the economic results obtained. This allows agricultural enterprises to make informed decisions on the feasibility of implementing certain innovations based on the cost-benefit ratio (Table 4).

***Table 4** . Costs and economic benefits of implementing innovative solutions in the agricultural sector of Kazakhstan*

Technology	Implementation costs (KZT mn)	Yield growth (%)	Reduction of losses (%)	Increase in value added (%)	Economic benefit (KZT mn)
Digitalisation of processes	10	15%	10%	12%	12
Agrodrones for monitoring	5	10%	5%	8%	6
Precision farming systems	7.5	20%	15%	18%	15

***Source:** compiled by the authors of this study based on Z. Taishykov et al. (2023)*

Each technology requires varying implementation costs but brings its own economic benefits. For example, digitalisation of processes requires an investment of KZT 10 mn, while it can increase yields by 15%, reduce losses by 10% and increase value added by 12%, which in total brings benefits of KZT 12 mn. Agrodrones require less cost (KZT 5 mn) and produce lesser results, but they also positively influence the growth of yields and reduction of losses. Precision farming systems, albeit requiring greater costs (KZT 7.5 mn), provide the greatest economic benefits, including a 20% increase in yields, 15% reduction in losses, and 18% increase in value added, giving an economic benefit of KZT 15 mn. Thus, the cost-effectiveness method enables a comprehensive assessment of the economic feasibility of introducing innovative solutions in the agricultural sector, providing information on which technologies will provide the greatest return on investment. Expert questionnaire survey is a method in which the opinions of agrocluster participants such as farmers, representatives of scientific institutions, and entrepreneurs are collected. This method helps to obtain qualitative information on the perception of innovation within the cluster, as well as to identify barriers and obstacles that may hinder the introduction of innovative technologies. The survey questions can be related to the level of innovation readiness, assessment of the need for innovative technologies, as well as problems of interaction between different cluster members. The data obtained offers a better insight into the internal problems and needs of the agrocluster, which helps to develop adequate measures to stimulate innovative development (Trushkina & Dzwigol, 2024).

Socio-economic analysis is also significant to assess the level of investment in R&D activities and the agrocluster's involvement in global supply chains. This method helps to understand how integrated the agrocluster is in the international economy and what

resources it uses for its development. Significant indicators here are the amount of investment in R&D, which directly affects the cluster's ability to develop and implement the latest technologies, and the extent to which the cluster is involved in global supply and knowledge sharing networks. An elevated level of integration of an agrocluster into international processes indicates its competitiveness and ability to adapt to changing global market conditions (Duy & Huong, 2024). Thus, the methodology for assessing the innovation potential of agroclusters includes several complementary approaches, each of which provides a better understanding of the current opportunities and constraints for innovation development in the agricultural sector. The use of SWOT-analysis, index method, expert assessments, and socio-economic analysis helps to form a comprehensive picture and develop a strategy aimed at increasing innovation activity and competitiveness of the agrocluster. These methods together allow not only understanding the current level of innovation potential, but also identifying ways to improve it, which contributes to more effective development of the agricultural sector overall.

The innovation potential of agroclusters depends on a variety of factors that can both favour their development and limit the opportunities for the introduction of innovative technologies. These factors include geographical location, climatic conditions, the level of cooperation between cluster members, government support, and infrastructure provision. Geographical location and climatic conditions play a vital role in determining the opportunities for agricultural development and, consequently, innovation in agro-production. The availability of natural resources such as water, land, minerals, and climatic conditions directly influence the choice of agricultural products that can be successfully grown in a particular region. For instance, for northern regions with short growing seasons, innovations in greenhouses, agrotechnics, and crop protection are particularly valuable to maximise the use of limited resources. Whereas for southern regions, where the climate favours a longer growing season for a variety of crops, special attention can be given to drought tolerance, innovative irrigation methods, and high-yielding varieties. Thus, geographical location and climatic conditions not only determine the specificity of agriculture but also dictate areas for the introduction of innovative technologies aimed at overcoming the specific challenges of the region (Yuan *et al.,* 2024).

Regions with developed cluster infrastructure demonstrate significantly higher rates of investment attraction. For instance, in Central and Eastern Europe (CEE), around 1,000 startups from more than 110 cities attracted a combined EUR 2.1 bn of investment in 2023, indicating high investment activity in these regions. Specifically, countries such as Poland, Ukraine, and Estonia contributed significantly to the total investment volume, with EUR 49 bn, EUR 28 bn, and EUR 28 bn, respectively. Furthermore, in Central Asia and the South Caucasus, including Kazakhstan, Uzbekistan, and Armenia, venture capital funding has grown 5.5-fold over the past five years, reaching USD 110 mn in 2023, and the number of start-ups has increased six-fold to 6,000. This data emphasises that regions with developed cluster infrastructure not only attract extensive amounts of venture capital but also contribute to the growth of the number of start-ups and their investment attractiveness (Over 1,000 startups…, 2024). The level of cooperation between cluster members also markedly affects the innovation potential of agroclusters. The existence of active partnerships between the different actors – producers, research institutions, processors, and technology companies – facilitates faster innovation. When farmers, researchers, and entrepreneurs work in close cooperation, it allows not only to share knowledge and experience, but also to jointly develop innovative technologies, solve practical problems, and reduce the risks associated with the introduction of new solutions. For example, close cooperation with scientific institutions can lead to the development of new plant varieties resistant to diseases and adverse conditions, while cooperation with processing companies can optimise supply chains and improve the quality of end products. It is essential that collaboration and trust mechanisms exist in an agrocluster to enable participants to share information and resources effectively, and to ensure successful innovation at all levels of the production process (Wardhana *et al.,* 2021).

Government support and policies are key factors that stimulate innovation activity in agroclusters. Subsidy programmes and grant support for innovation projects in the agribusiness sector play a leading role in financing research, developing innovative technologies, and bringing innovations into production. In countries with active state support for the agricultural sector, innovations are often implemented much faster, as farmers and entrepreneurs have access to the necessary finance to implement innovative solutions. Technology subsidies, tax incentive programmes for innovative enterprises, and research grants help to attract investment and stimulate innovation. Additionally, public policies can include an enabling environment for the adoption of digital technologies, biotechnology, and cleaner production methods, which also positively influence the innovation potential of agroclusters (Sarma *et al.,* 2022).

Investment in digital technologies considerably affects economic growth, especially in agriculture. For example, studies suggest that the development of digital agriculture positively affects the green total factor productivity (GTFP). One study found that as digital financial services increased by 1 percentage point, GTFP productivity increased by 0.0866 percentage points. Analogously, a one unit increase in the digital economy improved rural export competitiveness by 1.596

units. These findings confirm the existence of a multiplier effect of digital investment leading to pronounced economic growth in the agricultural sector (Zhou *et al.,* 2023). Infrastructural support forms an integral part of the innovation potential of agroclusters. The availability of logistics centres, digital platforms, laboratories, and agrotechnoparks can markedly improve the efficiency of innovation processes in the agribusiness sector. Logistics centres that ensure fast and efficient transport of products help to reduce costs and expedite the process of bringing new products to market. Digital platforms that enable data exchange between agribusiness participants optimise agricultural production management processes, improve yield forecasting, and increase the accuracy of agronomic calculations. Agrotechnological parks and laboratories play a key role in the development and testing of the latest technologies, providing access to the necessary equipment and professional specialists. All these infrastructure elements create conditions for effective innovation, provide support for start-ups and new agro-projects, and help create synergies between academia and industry (Bahodirjon & Hafizaxon, 2021).

The innovation potential of agroclusters depends on many interrelated factors. Geographical location and climatic conditions determine the specifics of agrarian production, the level of cooperation between cluster members promotes knowledge sharing and accelerated technology adoption, while government support and infrastructure provision create favourable conditions for innovative development. The integrated development of these factors is the key to the successful functioning of agroclusters and their ability to introduce innovations, increase productivity, and adapt to changes in the conditions of modern agribusiness. Agroclusters with strong innovation potential play a crucial role in the development of agriculture, introduction of innovative technologies, and increasing the sustainability of agro-production. Examples of such clusters can be found in different parts of the world, where innovations are actively implemented to improve the efficiency, sustainability, and competitiveness of agricultural regions (Table 5).

***Table 5**. Level of financing, innovation costs, and technology adoption in successful agroclusters*

Agrocluster	Level of financing (USD bn)	Innovation costs (USD bn)	Technology adoption (%)
Kazakhstan agro-industrial cluster	2.5	0.8	60%
Foodvalley (the Netherlands)	10	4.2	85%
California agrocluster (USA)	15	6.5	90%
Iowa agrocluster (USA)	7	2.8	75%

***Source:** compiled by the authors of this study based on A. Tkacheva et al. (2024)*

Kazakhstan's agro-industrial cluster is one of the examples of successful implementation of innovative technologies in agriculture. In recent years, Kazakhstan has been actively developing its agro-industrial complex, emphasising the introduction of precision farming technologies and digital solutions. In 2023, investments in agro-technologies totalled USD 2.5 bn, and the level of implementation of digital solutions reached 60%. One of the key areas of focus is the use of IoT to monitor crop health, control soil moisture, and determine the best timing for agronomic interventions. Currently, over 1,200 farms across the country are using IoT sensors to monitor soil microclimate. Drones are used for aerial photography and plant health monitoring, allowing farmers to react quickly to changes and make prompt decisions to improve crop yields. Kazakhstan has more than 500 agricultural enterprises using advanced digital technologies, including automated irrigation systems, AI-based crop forecasting, and cloud-based farm management platforms. Kazakhstan is also actively investing in innovative technologies to improve agricultural logistics, including warehouse automation and blockchain-based supply chain management systems. As a result, product losses at the storage and transport stages have decreased by 15%, and average yields on leading farms have increased by 20% (Ryskeldi *et al.,* 2024).

The specifics of agro-industrial complex development in different regions of Kazakhstan also play a significant role in the development of innovation potential (Table 6). For instance, North Kazakhstan Oblast is known for its grain production, where innovative methods are actively implemented to increase yields and improve grain quality. South Kazakhstan Oblast, specialising in cotton and vegetables, actively uses technologies to improve irrigation and minimise water losses. Almaty Oblast, with developed horticulture and livestock farming, is actively introducing modern technologies for herd management, as well as applying monitoring systems in greenhouses to improve fruit and vegetable yields. These specific regional features require distinctive approaches to technology implementation, which makes Kazakhstan one of the leaders in agrarian innovation in the post-Soviet space.

***Table 6**. Key agrarian specialisations and indicators of agricultural production in the regions of Kazakhstan*

Region	Primary specialisation	Major agrarian areas	Notes
North Kazakhstan Oblast	Grain production	Production of wheat, barley, maize, introduction of precision farming technologies, improvement of grain quality.	In 2023, the wheat harvest was 3.5 mn t, the average yield was 2.2 t/ha.
South Kazakhstan Oblast	Cotton and vegetable cultivation	Cotton growing, vegetable growing (tomatoes, cucumbers), improvement of irrigation system, application of the latest agro-technologies.	Cotton production – 60 thsd t/ year; 250 thsd ha of irrigated land.
Almaty Oblast	Horticulture and animal husbandry	Horticulture (apples, grapes), development of dairy and beef cattle breeding, innovations in herd management and monitoring systems in greenhouses.	Apple harvest – 150 thsd t; cattle population – 1.2 mn heads.

***Source:** compiled by the authors of this study based on G. Alibekova et al. (2023)*

The Dutch agrocluster Foodvalley (n.d.) is an example of one of the most technologically advanced agricultural clusters in Europe. The Netherlands, being a world leader in agricultural technology, has created a unique agrocluster Foodvalley, which has become a centre for research and implementation of innovative solutions in the agricultural sector. In 2023, funding for innovative projects in this cluster totalled USD 10 bn, with the share of R&D expenditure reaching USD 4.2 bn. One of the key areas of focus in Foodvalley is the prominent level of automation in agricultural production, which includes the use of robotic systems for planting and harvesting, as well as automatic systems for controlling temperature and humidity in greenhouses. As a result, the level of automation in greenhouse farms has reached 85% and the average yield of tomatoes and cucumbers has increased by 40% compared to conventional methods. Importantly, up to 95% of all greenhouses in the Netherlands use closed-loop water recycling systems, which reduced freshwater consumption by 60%. The Netherlands is also focusing on sustainable agriculture, including developing environmentally friendly technologies, minimising the use of chemical fertilisers and pesticides, and applying innovative water management solutions. A prominent component of the agrocluster is innovative greenhouses that utilise LED lighting, vertical farming, and autonomous moisture control systems. These advances made the Netherlands a global example of sustainable and highly efficient agricultural production, with exports valued at EUR 120 bn per year, making the country the second largest exporter of agricultural products in the world after the US.

US agroclusters, such as those in California and Iowa, also demonstrate a prominent level of innovation potential. These regions are actively using biotechnology and artificial intelligence to solve agricultural production problems. In California, in 2023, the volume of investments in biotechnological developments totalled USD 15 bn, which allowed implementing 90% of automated agricultural solutions. Here, genetically modified crops resistant to disease, drought, and pests are widely used, which increased maize and soybean yields by 25% and reduced pesticide use by 40%. Automated farm machinery technology is also being actively developed here, including unmanned tractors, Global Positioning System (GPS) navigation, and machine vision for automated fruit and vegetable harvesting (Love, 2024). In Iowa, USD 7 bn was allocated for innovation, with AI adoption rates reaching 75%. AI is being used to predict crop yields, analyse soil and weather data, enabling a more accurate determination of the best timing for planting and harvesting. The adoption of these technologies resulted in a 20% reduction in agricultural production costs and a 35% increase in average farm yields (IOWA, 2023).

Furthermore, water-saving agriculture plays a significant role in the innovative development of US agroclusters: California has introduced intelligent drip irrigation systems that reduce water losses by 50%, while Iowa is actively using carbon-neutral farming technologies to reduce carbon dioxide emissions by 30% through the use of biochar fertilisers and crop rotation. Examples of agroclusters show how implementing innovative solutions in agriculture leads to greater yields, lower costs, reduced wastage, and increased environmental sustainability. The use of digital technology, artificial intelligence, robotic systems, and precision farming is achieving a highly competitive position in the global market. Importantly, the success of each of these clusters is driven by a systemic approach, government support, investment in R&D, and effective cooperation between academic institutions, businesses, and producers. These examples highlight the value of an integrated approach to the development of agricultural technologies and can become a basis for the development of effective agricultural modernisation strategies in other countries. To achieve sustainable growth and innovative development of agroclusters, it is necessary to take comprehensive measures aimed at creating a favourable environment for the introduction of innovative technologies and effective use of existing capabilities. In this context, several key recommendations can substantially contribute to increasing the innovation potential of agrarian regions.

Establishing agro-innovation centres is a major step towards introducing the latest agrarian technologies

and accelerating knowledge transfer between scientific institutions, entrepreneurs, and farmers. These centres can become key platforms for testing and disseminating innovative solutions in agriculture, as well as for conducting research aimed at solving specific problems of the agricultural sector. They can include research laboratories, agro-technoparks, and educational institutions where advanced technologies are developed and implemented. Agro-innovation centres can also act as intermediaries between public and private investors, helping to find resources for start-ups and agricultural projects. Such an approach will accelerate innovation and improve the competitiveness of agro-production. State support for startups in the agribusiness sector is a prerequisite for stimulating innovation activity. In conditions where agrarian start-ups face financial and organisational difficulties, support from the state through subsidies, grants, and tax incentives can become a decisive factor for their successful functioning. Government programmes aimed at the development of startups will provide them with access to the necessary resources, help them overcome the initial stage, and reduce financial risks. Grant and subsidy programmes can range from developing innovative technologies to supporting environmentally friendly and sustainable agriculture. Tax incentives for such enterprises will favour their long-term development and attract investment. Thus, support for innovative start-ups will facilitate the creation of fresh solutions and increase competition in the agricultural sector.

The development of digital infrastructure, including IoT, Big Data, and AI technologies, is key to increasing the innovation potential of agroclusters. Agriculture, like many other industries, faces the need to optimise processes, improve accuracy, and reduce costs. The adoption of IoT technologies allows farmers to monitor crop health, soil moisture levels, air temperature, and other critical parameters in real time to help make informed decisions. The use of Big Data and AI can markedly improve yield forecasting processes, analyse soil health data, and predict risks associated with climate change or pests. The creation and development of digital platforms for agribusiness and the implementation of such technologies at all levels of production will help agroclusters to significantly increase their efficiency, reduce losses and improve product quality. Integration of educational programmes for training specialists in agro-innovation is another valuable recommendation for increasing the innovation capacity of agroclusters. In the context of rapid technological progress, agriculture needs highly qualified specialists who can effectively work with the latest technologies and adapt them to the specifics of the region. The development of educational programmes focused on agro-innovation should include courses on modern technologies in agriculture, biotechnology, sustainable development, and digital solutions. It is vital that educational institutions work in close cooperation with agribusiness, research centres, and government agencies, which will not only train specialists, but also introduce relevant knowledge and solutions into the learning process. Additionally, the development of advanced training and retraining programmes for existing specialists will help to improve the overall technological literacy of the agricultural sector and prepare it for the challenges of the future.

Thus, the recommendations on the creation of agro-innovation centres, state support for startups, development of digital infrastructure, and integration of educational programmes are aimed at creating a sustainable and innovative ecosystem in the agricultural sector. These measures will help accelerate the process of introducing the latest technologies, improve the knowledge and skills of agricultural workers, and make agroclusters more competitive in the international arena. In the face of global challenges such as climate change and a growing world population, these steps will play a crucial role in ensuring food security and sustainable development of the agricultural sector.

DISCUSSION

The analysis of the innovation potential of agroclusters revealed that the key factors determining the success of such clusters include the availability of qualified personnel, research base, financial support, as well as developed technological infrastructure. First of all, human resources play a fundamental role. In regions with highly developed agroclusters, such as the Netherlands or the USA, the level of education and competence of specialists in the field of agricultural and innovative technologies directly affects the implementation of new solutions. For instance, in the agrocluster Foodvalley, due to the strong level of education and close interaction between universities and scientific institutions, successful projects in the field of sustainable agriculture and automation are implemented.

C.-I. Coman and V. Cojanu (2024) also investigated this problem, with their findings confirming that the value of human resources and education for the innovative development of agroclusters lies in their ability to ensure the effective implementation of the latest technologies and management practices. Highly skilled professionals play a key role in developing and implementing innovative solutions that help to improve agricultural competitiveness. Education and training in agroclusters contribute to the development of professionals capable of integrating advanced knowledge and skills into practice, leading to increased productivity and sustainability of agricultural enterprises. S. Imanuella *et al.* (2025) also showed that the role of skilled labour and innovative entrepreneurship in agroclusters is intricately linked to the development of social entrepreneurship and rural support. Social entrepreneurship creates more employment opportunities and improves the quality of life in rural areas through the

implementation of sustainable business models. Such initiatives help to attract investment and improve infrastructure, which supports the long-term development of agroclusters, increasing their social and economic significance.

Notably, successful innovative development of agroclusters requires not only a strong level of education and qualification of personnel, but also the creation of a favourable environment for innovation. This includes access to modern information technologies, as well as support from public and private investors. It is essential that specialists not only have theoretical knowledge, but also can apply it in practice, which is possible in close c-operation with agricultural enterprises, scientific institutions, and business (Ussenova *et al.*, 2023). The methodology for assessing the innovation potential of agroclusters was also analysed in detail. The findings showed that the use of SWOT-analysis allows identifying the strengths and weaknesses of the agrocluster, as well as possible threats and opportunities for further development. Innovation activity indices, such as the number of patents and the level of digitalisation, play an essential role in assessing the effectiveness of innovation processes. These methods allow identifying potential areas for improvement and directing efforts towards the most promising areas. Expert questionnaires and socio-economic analyses also showed the significance of involving all actors in the agrocluster, including farmers, research institutions, and processors, to obtain a comprehensive assessment of the situation.

O.I. Sayitkulovich *et al.* (2024) concluded that the methodology for assessing the organisational and economic efficiency of agroclusters includes an integrated approach combining various analytical tools. The use of expert surveys provides valuable information on the current state and needs of agroclusters, as well as identifying the primary problems and obstacles to their development. This method provides an opportunity to gain a deeper understanding of subjective factors that affect innovation processes and form an accurate picture of the potential and risks of agrarian enterprises. A. Foglia *et al.* (2021) found that socio-economic analysis is a significant element in assessing the innovation activity of agroclusters, as it reveals the relationship between the adoption of innovative technologies and social outcomes. This method allows assessing how innovation initiatives affect the improvement of living conditions of the population and the development of the region. Combining expert surveys with socio-economic data provides a more comprehensive picture of the influence of innovation projects on the economy and social sphere of the agrocluster, which contributes to more objective policy and management decisions. These results corroborate the conducted study as they demonstrate analogous findings on the significance of an integrated approach to assessing the performance of agroclusters. Expert surveys and socio-economic analyses identify not only current problems but also prospects for sustainable development of agribusinesses. These tools help to identify the factors affecting innovation processes more accurately and allow developing recommendations to improve the organisational and economic structure of agroclusters, which was confirmed by analogous studies in other regions.

Factors affecting the innovation potential of agroclusters were also considered in the context of geographical and climatic conditions. For instance, the North Kazakhstan region, known for its grain production, is characterised by specific climatic conditions that require the introduction of precision farming technologies to increase yields. At the same time, South Kazakhstan Oblast, which specialises in cotton and vegetables, needs technologies that optimise water and energy consumption. The influence of government support and policies also proved to be a decisive factor for the development of innovative solutions in agroclusters. In countries with developed agro-economies, such as the Netherlands, USA, and Kazakhstan, government programmes aimed at subsidising innovative projects and stimulating private investment are actively implemented (Malik *et al.*, 2024). A. Mukumov *et al.* (2021) also found that geographical and climatic conditions play a crucial role in the innovation potential of agroclusters, as they influence the choice of applied agricultural technologies and business practices. The specificity of the region determines the opportunities to adopt sustainable agronomic solutions such as drip irrigation, use of crop rotation, and adapted crops. In regions with unfavourable climatic conditions, innovative approaches become particularly significant to increase productivity and minimise the risks associated with climate change.

D.B. Olimjonovich and K. Jakhongir (2024) concluded that state support and cooperation of agrocluster participants serve as a basis for the development and implementation of innovative technologies in the agricultural sector. Effective interaction between government agencies, research institutions, and entrepreneurs contributes to the creation of a favourable innovation ecosystem, where the exchange of knowledge and resources helps to overcome technological barriers. A vital element in this process is support from the authorities, which stimulates the development of business activity in rural areas and promotes the implementation of the latest solutions aimed at improving the competitiveness of agroclusters (Khrystenko *et al.*, 2025). These findings are consistent with the theses presented in the previous section, as they confirm that geographical and climatic factors form an integral part of the innovation potential of agroclusters. The specific location and natural conditions influence the choice of appropriate technologies and strategies to optimise agricultural production (Shuvar *et al.*, 2022; Andreitsev *et al.*, 2024). Thus, the integration of modern solutions in the agricultural sphere is impossible without factoring

in the specifics of the region, which is also reflected in the successful examples discussed in the previous section of this study.

Examples of successful agroclusters with prominent innovation potential, such as the Kazakhstan agro-industrial cluster, Foodvalley in the Netherlands, and agroclusters in the USA, demonstrated remarkable achievements in the implementation of innovative technologies. For example, in Kazakhstan, the application of precision farming technologies and the use of drones to monitor crops resulted in improved agricultural efficiency and reduced losses in storage and transport of produce. In the Netherlands, high levels of agricultural automation, including robotic harvesting systems and innovative greenhouses, resulted in high productivity and sustainable agro-production. These examples showed how the integration of innovative technologies can substantially improve the competitiveness and sustainability of agricultural sectors in different countries.

M.W. Sitnicki *et al.* (2024) confirmed that examples of successful agroclusters with high innovation potential demonstrate the value of strategically forming agrarian market clusters to achieve global competitive advantage. In agroclusters such as the one in Ukraine, there is a synergy between agricultural producers, research institutions, and government agencies, which facilitates the adoption of innovative technologies and increases overall productivity. These clusters actively utilise modern agro-technologies and allocate resources efficiently, making them role models in the international arena. M. Saidov and I. Ochilov (2023) also found that the sustainability of agroclusters becomes a key factor in their long-term development as it enables them to adapt to changing market conditions and environmental challenges. Sustainability is achieved through the adoption of sustainable agricultural practices such as the utilisation of renewable resources, ecological innovation, and support for biodiversity. Good governance and the ability to respond flexibly to changes in the external environment ensure that such agroclusters are sustainable, which is particularly significant in the context of global competition and climate change.

Comparing the data from the studies, it can be observed that successful agroclusters with prominent innovation potential do share a series of features, such as close cooperation between different actors in the ecosystem and active adoption of innovative technologies. These clusters demonstrate the ability to adapt to changing market conditions and ensure long-term economic sustainability. Their success can be attributed not only to the integration of innovation, but also to a strategic approach to resource management, as evidenced by studies in different countries. It was noted that the development of innovation potential of agroclusters plays an essential role in ensuring sustainable development of the agricultural sector and increasing its competitiveness. An integrated approach, including scientific research, government support, technological infrastructure development, and human resources, contributes to the creation of effective agroclusters (Pavliv, 2023). The development of agro-innovation in such clusters leads to the creation of new jobs, improved product quality, and increased economic sustainability of the regions.

P. Rambe and P. Khaola (2022) concluded that the influence of innovation on the sustainability and competitiveness of agricultural regions cannot be underestimated, as the introduction of innovative technologies helps to improve production efficiency and reduce risks associated with climate change and market fluctuations. Innovation allows agricultural regions to optimise pro cesses, use resources more efficiently, and reduce production costs, making them more resilient to external economic and environmental challenges. The application of advanced technologies in agriculture also contributes to the improvement of product quality, which is a significant factor for competitiveness in the global market (Mamasydykov *et al.*, 2019). T.S. Jayne *et al.* (2021) revealed that the innovation capacity of the agricultural sector directly affects economic growth and stability, as the introduction of new methods and solutions increases productivity and stimulates job creation. The development of high-tech industries, such as agro-processing or the use of smart agricultural systems, contributes to the diversification of the region's economy and the creation of sustainable supply chains. Innovation plays a key role in long-term economic stability, as it provides greater incomes for farmers and businesses, and helps reduce dependence on external economic factors such as changes in commodity prices or climate risks.

Analysis of the findings of the study, clearly shows that innovation plays a key role in improving the sustainability and competitiveness of agricultural regions. The introduction of innovative technologies not only improves production processes but also helps agrarian enterprises to adapt to changes in the external environment, such as fluctuations in market prices or changes in climate (Pasichnyk *et al.*, 2023). These factors make regions that actively innovate more flexible and can respond to challenges effectively, which is confirmed by the successful examples of agroclusters considered in the study. Based on the findings, recommendations for further development of agroclusters were proposed. First of all, it is necessary to create agro-innovation centres, which will facilitate the introduction of innovative technologies and knowledge transfer between participants in agro-production, scientific institutions, and government agencies. The development of state support for start-ups in the agribusiness sector through subsidies, grants, and tax incentives is also a major step. Finally, it is necessary to develop digital infrastructure, including the use of IoT, Big Data, and artificial intelligence to better manage agribusiness and increase yields.

CONCLUSIONS

The study of innovation potential of agroclusters revealed that their development directly depends on several key factors such as human resources, research and development base, financial support, and technological infrastructure. Successful interaction between government agencies, research institutions, and private companies plays a crucial role in achieving meaningful outcomes in the agricultural sector. Examples of such effective agroclusters are regions with prominent levels of innovation, such as the Netherlands, Kazakhstan, and the USA. In Kazakhstan, the level of agribusiness financing is USD 2.5 bn, of which USD 0.8 bn is allocated to innovation spending. This demonstrates the government's commitment to investing in the development of innovative technologies and solutions for the agribusiness sector. In the Netherlands, particularly in Foodvalley, the level of agrocluster financing is much higher, reaching USD 10 bn, of which USD 4.2 bn is allocated on innovation spending. In the US, in agroclusters such as California and Iowa, funding reaches USD 15 bn and USD 7 bn respectively, with innovation spending of USD 6.5 bn and USD 2.8 bn. These data underscore the significance of investment in innovation, which directly contributes to improving the technology base and agricultural productivity.

Furthermore, successful agroclusters are actively adopting advanced technologies such as precision farming, IoT, biotechnology, and artificial intelligence. These technologies not only increase productivity but also make agriculture more resilient to climate change and economic fluctuations. The methodology for assessing the innovation potential of agroclusters, including SWOT analysis, index method, and expert questionnaires, allows accurately identifying strengths and weaknesses and directing efforts to the development of the most promising areas. For instance, the introduction of innovations in Kazakhstan's agro-industrial complex has led to a 3.6% annual growth since 2010, while labour productivity has increased to USD 6.6 thsd per person. This is 30% greater than the indicators of Ukrainian farmers. The introduction of digital technologies in agriculture can considerably increase profitability by 50-100% in the first two years of use, highlighting the value of innovation for sustainable growth of the agricultural sector. For a deeper understanding, it is necessary to examine the impact of climate change on the innovation capacity of agroclusters and their ability to adapt to changing conditions.

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CONFLICT OF INTEREST

None.

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Аналіз інноваційного потенціалу регіональних агрокластерів

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Анотація. В рамках дослідження аналізуються ключові ресурси та умови, що впливають на розвиток інноваційної діяльності в регіональних агрокластерах. У дослідженні було проведено комплексний аналіз інноваційного потенціалу агрокластерів, що включає оцінку ключових факторів, таких як кадрові ресурси, науково-дослідна база, фінансова підтримка та технологічна інфраструктура з використанням SWOT-аналізу, індексного методу та експертів. Аналіз показав, що рівень інноваційного потенціалу регіональних агрокластерів визначається ступенем взаємодії між підприємствами, науковими установами та державними структурами. Фінансування агропромислового кластера в Казахстані становить 2,5 млрд доларів, з яких 0,8 млрд прямують на інновації, тоді як у Нідерландах, США (Каліфорнія та Айова) ці показники значно вищі, досягаючи 10-15 млрд доларів з інноваційними витратами від 2,8 до 6,5 млрд доларів. Наприклад, у Казахстані з 2010 року спостерігається стабільне зростання агропромислового комплексу на 3,6 % на рік, що сприяло збільшенню продуктивності праці до 6,6 тис. доларів на людину – на 30 % вище за показники українських фермерів. Встановлено, що наявність спеціалізованої інфраструктури (агротехнопарків, центрів трансферу технологій) сприятиме прискореному впровадженню інновацій. Дослідження також підтвердило, що ключовими бар'єрами для інноваційного розвитку агрокластерів є недостатнє фінансування науково-дослідних та дослідно-конструкторських робіт, нестача кваліфікованих кадрів та слабка кооперація між учасниками. Наприклад, використання технологій точного землеробства та штучного інтелекту може збільшити врожайність на 20 % та знизити використання води на 30 %. У регіонах з активною державною підтримкою та доступом до інвестицій, таких як Казахстан, спостерігається зростання кількості стартапів та венчурних інвестицій. На підставі проведеного аналізу запропоновано рекомендації щодо розвитку інноваційного потенціалу агрокластерів, включаючи створення стимулюючих заходів підтримки, розвиток освітніх програм та впровадження цифрових платформ для обміну технологіями. Отримані результати можуть бути використані для розробки стратегій підтримки та стимулювання інноваційної активності в регіональних агрокластерах, що сприяє підвищенню їхньої конкурентоспроможності та ефективності

Ключові слова: цифровізація; державна підтримка; кооперація; інвестиції; технології; інфраструктура