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08.00.03 Sanoat iqtisodiyoti
08.00.04 Qishloq xo‘jaligi iqtisodiyoti
08.00.05 Xizmat ko‘rsatish tarmoqlari iqtisodiyoti
08.00.06 Ekonometrika va statistika
08.00.07 Moliya, pul muomalasi va kredit
08.00.08 Buxgalteriya hisobi, iqtisodiy tahlil va audit
08.00.09 Jahon iqtisodiyoti
08.00.10 Demografiya. Mehnat iqtisodiyoti
08.00.11 Marketing
08.00.12 Mintaqaviy iqtisodiyot
08.00.13 Menejment
08.00.14 Iqtisodiyotda axborot tizimlari va texnologiyalari
08.00.15 Tadbirkorlik va kichik biznes iqtisodiyoti
08.00.16 Raqamli iqtisodiyot va xalqaro raqamli integratsiya
08.00.17 Turizm va mehmonxona faoliyati

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MUNDARIJA СОДЕРЖАНИЕ CONTENTS

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MUNDARIJA СОДЕРЖАНИЕ CONTENTS

INNOVATIVE TRANSFORMATION PROCESSES AND ADVANCED INTERNATIONAL EXPERIENCE IN THE FIELD OF AGRICULTURAL SERVICES

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Abstract. This scientific article examines innovative transformation processes and advanced international experience in the field of agricultural services. Agriculture is considered one of the strategically important sectors in ensuring food security, increasing export potential, creating employment opportunities, and supporting sustainable economic development under conditions of rapid population growth. The study analyzes innovative approaches aimed at improving agricultural productivity, strengthening monitoring and control systems, and ensuring efficient use of natural resources in accordance with modern economic and environmental requirements.

The article highlights the growing global environmental challenges, including water scarcity, soil degradation, and climate change, which are particularly relevant for arid regions such as Uzbekistan. Special attention is paid to regenerative agriculture practices, including conservation tillage, soil fertility restoration, crop rotation, and minimum tillage technologies, which contribute to soil regeneration, carbon sequestration, and sustainable land management.

In addition, the concept of carbon farming is explored as an important mechanism for creating economic incentives for farmers to adopt environmentally friendly and climate-resilient agricultural practices. The research focuses on Uzbekistan's agricultural sector, which is highly dependent on irrigation systems, limited water resources, and vulnerable to land degradation processes. The study argues that modernization of the agro-service system through the adaptation of advanced international experience to local conditions can improve water-use efficiency, reduce environmental pressures, increase productivity, and enhance farmers' incomes.

The paper also emphasizes the growing role of agro-service providers as key intermediaries in technology transfer, knowledge dissemination, digital transformation, and the development of innovative agricultural ecosystems.

Key words: agri-services, ecological economy, green innovations, regenerative agriculture, ecology, artificial intelligence, carbon farming, climate change, digital agriculture.

Annotatsiya. Mazkur ilmiy maqolada qishloq xo'jaligi xizmatlari sohasidagi innovatsion transformatsiya jarayonlari hamda ilg'or xalqaro tajribalar tahlil qilinadi. Qishloq xo'jaligi aholining oziq-ovqat xavfsizligini ta'minlash, eksport salohiyatini oshirish, yangi ish o'rinlarini yaratish va barqaror iqtisodiy rivojlanishni qo'llab-quvvatlashda strategik ahamiyatga ega tarmoq sifatida baholanadi. Tadqiqotda zamonaviy iqtisodiy va ekologik talablar asosida qishloq xo'jaligi mahsulotlari ishlab chiqarishini samarali boshqarish, monitoring qilish hamda resurslardan oqilona foydalanishni ta'minlashga qaratilgan innovatsion yondashuvlar o'rganilgan.

Maqolada suv tanqisligi, tuproq degradatsiyasi va iqlim o'zgarishi kabi global ekologik muammolarning, ayniqsa O'zbekiston kabi qurg'oqchil hududlar uchun dolzarb ahamiyati yoritilgan. Shuningdek, regenerativ qishloq xo'jaligi amaliyotlari, jumladan tuproq unumdorligini tiklash, ekin almashinuvi, minimal ishlov berish texnologiyalari va ekologik barqaror agrotexnologiyalarning tuproq salohiyatini oshirish hamda uglerod yutilishini kuchaytirishdagi roli tahlil qilingan.

Bundan tashqari, uglerodli dehqonchilik konsepsiyasi fermerlarni ekologik xavfsiz va iqlimga moslashuvchan ishlab chiqarish usullarini qo‘llashga rag‘batlantiruvchi muhim iqtisodiy mexanizm sifatida baholanadi. Tadqiqot O‘zbekiston qishloq xo‘jaligining sug‘orishga yuqori darajada bog‘liqligi, suv resurslarining cheklanganligi va yer degradatsiyasi bilan bog‘liq muammolarini hisobga olgan holda olib borilgan. Tadqiqot natijalari shuni ko‘rsatadiki, agroxizmatlar tizimini ilg‘or xalqaro tajriba asosida mahalliy sharoitlarga moslashtirish suvdan foydalanish samaradorligini oshirish, ekologik bosimni kamaytirish, ishlab chiqarish hajmini ko‘paytirish hamda fermerlar daromadlarini oshirish imkonini beradi.

Maqolada agroxizmat ko‘rsatuvchi subyektlarning texnologiyalar transferi, bilim va ko‘nikmalarni rivojlantirish, raqamli transformatsiyani jadallashtirish hamda innovatsion agroekotizimni shakllantirishdagi muhim vositachi sifatidagi roli ham alohida ta’kidlangan.

Kalit so‘zlar: agroxizmatlar, ekologik iqtisodiyot, yashil innovatsiyalar, regenerativ qishloq xo‘jaligi, ekologiya, sun’iy intellekt, uglerodli dehqonchilik, iqlim o‘zgarishi, raqamli qishloq xo‘jaligi.

Аннотация. В данной научной статье рассматриваются инновационные трансформационные процессы и передовой международный опыт в сфере агросервисных услуг. Сельское хозяйство является одной из стратегически важных отраслей, обеспечивающих продовольственную безопасность, развитие экспортного потенциала, создание занятости населения и устойчивый экономический рост в условиях увеличения численности населения. В исследовании анализируются инновационные подходы, направленные на повышение производительности сельского хозяйства, совершенствование систем мониторинга и контроля, а также обеспечение рационального использования природных ресурсов в соответствии с современными экономическими и экологическими требованиями.

В статье особое внимание уделяется глобальным экологическим проблемам, таким как дефицит водных ресурсов, деградация почв и изменение климата, которые особенно актуальны для засушливых регионов, включая Узбекистан. Исследуются методы регенеративного сельского хозяйства, в том числе почвозащитная обработка, восстановление плодородия почв, севооборот и минимальная обработка земли, способствующие восстановлению почв, накоплению углерода и устойчивому управлению земельными ресурсами.

Кроме того, концепция углеродного земледелия рассматривается как важный механизм формирования экономических стимулов для внедрения экологически безопасных и климатически устойчивых методов ведения сельского хозяйства. Исследование сосредоточено на сельском хозяйстве Узбекистана, которое характеризуется высокой зависимостью от орошения, ограниченностью водных ресурсов и проблемами деградации земель. В работе обосновывается, что модернизация системы агросервисов на основе адаптации передового международного опыта к местным условиям позволит повысить эффективность использования воды, снизить экологическую нагрузку, увеличить производительность и доходы фермеров.

Также подчеркивается возрастающая роль поставщиков агросервисных услуг как ключевых посредников в передаче технологий, распространении знаний, цифровой трансформации и формировании инновационной аграрной экосистемы.

Ключевые слова: агросервисы, экологическая экономика, зеленые инновации, регенеративное сельское хозяйство, экология, искусственный интеллект, углеродное земледелие, изменение климата, цифровое сельское хозяйство.

INTRODUCTION

Today, agriculture is one of the strategic sectors of the economy of Uzbekistan, playing an important role not only in providing the population with food products, but also in increasing the country’s export potential, creating employment opportunities in the regions, and ensuring social stability. More than 60 percent of the territory of the republic is suitable for agricultural activity, while the share of agriculture in the gross domestic product (GDP) amounted to 25.5 percent in 2023[1]. Although agricultural production has been steadily increasing in recent years, the efficiency of production and resource utilization still remains below the level observed in developed countries.

The acceleration of scientific and technological progress worldwide, the expansion of the digital economy, and the growing importance of environmental sustainability require the introduction of new approaches in the agricultural sector. In this context, an innovative agro-services system is emerging as an integral component of modern agricultural production. This system contributes not only to the automation and digitalization of production processes, but also to improving product quality, productivity, logistics efficiency, and marketing mechanisms.

1 https://www.navstat.uz/uz/matbuot-markazi/qo-mita-yangiliklar/11677-yaim-yahm-ning-tarmoqlar-bo-yicha-tarkibida-qishloq-o-rmon-va-baliqchilik-xo-jaligining-ulushi-qanday-6?utm

Innovative agro-services refer to the application of advanced technologies, digital management tools, scientific research outcomes, and modern service models in agriculture. These include smart irrigation systems, monitoring of agricultural land through drones and artificial intelligence technologies, real-time resource management via digital agro-platforms, the use of biofertilizers and biopesticides, as well as the development of cold-chain logistics and export certification services.

The development of an innovative agro-services system in Uzbekistan is associated with several important challenges. Agricultural producers often lack sufficient knowledge and practical skills for the effective implementation of modern technologies. In addition, the costs of innovative equipment and agro-services remain relatively high. The infrastructure of agro-technological parks, agro-clusters, and digital agro-platforms is still developing, while the participation of the private sector in the agro-services market requires further expansion. Moreover, the process of transferring scientific research results into practical application remains gradual and needs further improvement.

At the same time, the reforms implemented by the government in recent years are creating favorable conditions for the development of innovative agro-services. In particular, the “Agricultural Development Strategy of Uzbekistan until 2030,” digital agriculture programs, and measures aimed at expanding public-private partnership mechanisms in the agricultural sector are strengthening the institutional basis for innovation. Between 2020 and 2023, more than 25 agro-technoparks and agro-clusters were established in Uzbekistan, within which over 500 projects focused on the introduction of modern technologies were implemented.

International experience demonstrates that the widespread adoption of innovative agro-services systems can increase agricultural efficiency by 20–40 percent. In countries such as Israel, the Netherlands, and the United States, these systems contribute not only to higher productivity, but also to environmental sustainability through the efficient use of water, energy, and other natural resources.

This article analyzes the theoretical and methodological foundations of the formation and development of innovative agro-services systems, the mechanisms for their implementation within the context of Uzbekistan, performance indicators, and advanced international and domestic experiences. The main objective of the study is to develop theoretical and practical recommendations aimed at improving the efficiency of agricultural production through the development of innovative agro-services systems.

LITERATURE REVIEW

The theoretical and methodological foundations for the development of agro-services in agriculture are formed on the basis of multidisciplinary approaches. Agro-services essentially represent a complex system of services aimed at supporting agricultural producers — including farms, agro-clusters, cooperatives, and processing enterprises — at all stages of the production process. These services encompass a broad range of activities, including technical and technological support, information and communication technologies (ICT), financing, marketing, logistics, consulting, and innovation transfer. Their theoretical significance lies in the fact that agro-services constitute an independent component of the agricultural production system, contributing to increased production efficiency, rational use of resources, improvement of product quality, and rapid adaptation of producers to changing market conditions.

In his classical works on service management and marketing, Grönroos emphasizes that real value is created through interaction with customers, highlighting the “service–customer value–profit” chain. Applied to the agro-services sector, this approach demonstrates that the quality of services such as equipment leasing, consulting, certification, logistics, and digital support directly influences farmers’ productivity and economic outcomes. Therefore, indicators such as perceived quality, reliability, responsiveness, and operational efficiency should be assessed simultaneously. Grönroos’s more recent studies expand the concept of “service profit logic” and provide a systematic framework for the development of integrated service systems, thereby justifying “one-stop-shop” models in agro-services markets.

Porter’s value chain concept also provides an important theoretical basis for understanding the role of agro-services in agriculture. According to Porter, value is generated throughout all stages of the production and distribution process. In agriculture, agro-services create additional value within the interconnected processes of seed production, cultivation, storage, logistics, processing, and marketing. Kaplinsky and Morris further developed this approach by applying value-chain analysis in developing countries, emphasizing chain mapping, governance mechanisms, and upgrading opportunities. Their framework demonstrates how agro-services such as cold-chain logistics, quality certification, and digital monitoring systems contribute to competitiveness and export potential.

Klerkx and Leeuwis (2009) focus on the role of innovation brokers within Agricultural Knowledge and Innovation Systems (AKIS/AIS). According to their research, innovation intermediaries facilitate cooperation among stakeholders, accelerate knowledge and technology transfer, and strengthen trust-based communication

between research institutions, farmers, businesses, and policymakers. This function is especially important in linking market demands with practical agricultural outcomes and ensuring the successful implementation of innovative technologies.

The Food and Agriculture Organization (FAO), through its “Save and Grow” and Sustainable Crop Production Intensification concepts, advocates increasing agricultural productivity while simultaneously reducing environmental pressure. This approach promotes resource-efficient and environmentally sustainable farming practices, including field-specific fertilization, water-saving irrigation systems, integrated pest management, conservation agriculture, and organic matter management. Within this framework, agro-services are considered essential instruments for disseminating modern technologies and advisory support to farmers. Consequently, agro-services not only contribute to reducing production costs and resource consumption, but also enhance ecosystem sustainability and long-term agricultural productivity[2].

RESEARCH METHODOLOGY

This article is based on a multi-methodological research approach. The methodological principles underlying the development of the agro-services sector in agricultural production provide a scientific basis for organizing the sector through a systematic approach, increasing efficiency, and ensuring flexibility in response to market requirements. These principles define the conceptual foundations of the agro-services system and determine the methodological directions for improving development mechanisms.

The methodological approach used in the study simultaneously considers economic, organizational, technological, and social factors, since the agro-services system possesses a multi-sectoral and multi-level structure. In particular, the principle of integration and cooperation plays a crucial role, according to which agro-services should operate in close interaction with production, processing, logistics, marketing, and other interconnected sectors of the agricultural economy.

The research methodology is aimed at improving the theoretical, methodological, and practical foundations of organizational and economic mechanisms that support the effective development of green innovative activities within the agricultural services sector. Methodological approaches, scientifically grounded recommendations, and conclusions developed in the course of the study contribute to strengthening the efficiency and sustainability of agro-services under modern economic conditions.

The scientific results obtained in the research are based on contemporary methodological approaches. In particular, abstraction was applied to identify the most significant aspects of the research problem; analysis and synthesis methods were used for an in-depth study and generalization of economic and organizational processes; while induction and deduction methods ensured the logical consistency and scientific validity of the conclusions.

ANALYSIS AND RESULTS

In Uzbekistan, the development of green innovations in the agricultural sector, the systematic improvement of the effectiveness of scientific research, and the broad implementation of research outcomes into production practice have been identified as priority directions of the state agrarian policy. As a result of the comprehensive institutional reforms implemented under the leadership of the government, improvements in the regulatory and legal framework, and the development of innovative infrastructure, the opportunities for applying scientific achievements in practice have significantly expanded. At the same time, the necessary organizational and economic conditions for achieving sustainable and high-performance results in the agricultural sector have gradually been formed.

In modern economic theory and practice, the competitiveness of education and science systems is recognized as one of the key indicators determining the level of sustainable development of any country. The level of development of these systems directly influences the innovation orientation of the economy, the efficiency of scientific potential utilization, and the ability to produce high value-added products. Therefore, in the experience of developed countries, special attention is paid to the continuous modernization of science and education systems, strengthening their integration, and ensuring effective cooperation between scientific research institutions and the real sector of the economy.

This process requires not only continuous investment in science and education, but also the formation of a flexible institutional structure capable of responding to modern challenges and technological changes. In this regard, the experience of Israel in developing innovative agro-services deserves particular attention, as the country has achieved significant success in agricultural innovation despite limited natural resources and difficult climatic conditions.

2 The 2011-2012 project ,,Support for Farmers Cooperatives’’

Israel is located on the eastern coast of the Mediterranean Sea and is characterized by predominantly arid and semi-arid climatic conditions. The amount of precipitation is relatively low and mainly occurs between October and April. Moreover, rainfall distribution across the country is uneven, with the northern regions receiving comparatively higher levels of precipitation.

The soil fertility conditions of the country are also limited, and only about 20 percent of the territory is considered suitable for agricultural activities. As a result, agricultural production is mainly concentrated in the central and northern regions of the country. Field crops are cultivated primarily in the valleys and in the northern parts of the Negev Desert, which occupies more than half of Israel's territory.

Despite difficult climatic conditions, constant water shortages, and the fact that nearly two-thirds of the country's territory consists of desert areas, Israel achieved approximately 19 percent growth in agricultural production during the period from 2005 to 2015. Such impressive results were made possible through close cooperation between the agricultural sector and scientific institutions, as well as the active implementation of advanced technologies and innovative agro-services[3].

In Israel, a significant portion of agricultural land is located in arid and semi-arid regions, while water resources for irrigation remain limited. Therefore, the country has focused its innovative agro-services policy on water resource management, increasing productivity, efficient resource utilization, and the digitalization of agricultural production processes. In particular, drip irrigation technologies developed in Israel since the 1960s are recognized as one of the most efficient water-saving technologies not only in the country but also worldwide. Today, Israeli companies such as Netafim, Metzerplas, and Rivulis occupy leading positions in the global irrigation market and export their technologies to hundreds of countries.

The Israeli agro-services system has developed in three major directions: scientific research and experimental testing services, production-technological support services, and safety and risk management services. Scientific research activities are mainly conducted at the Volcani Center and agricultural research departments of several universities. These institutions provide direct advisory services to farmers, test new crop varieties and technologies, and develop agrotechnical solutions adapted to local farming conditions.

For example, agro-service platforms based on the Israeli concept of "Precision Agriculture" enable farmers to monitor crop conditions in real time and optimize irrigation and fertilization regimes through satellite monitoring systems and Internet of Things (IoT) technologies. This contributes to reducing production costs, improving resource efficiency, and increasing productivity.

The economic efficiency of the Israeli agricultural model also deserves particular attention. According to data from the Food and Agriculture Organization and the World Bank, the value of agricultural products produced per hectare of land in Israel is approximately 2.5 times higher than the global average. Although only about 4–5 percent of the country's population is employed in agriculture, the volume of agricultural production is sufficient not only to satisfy domestic demand but also to support significant export activities. In this process, the agro-services sector accounts for nearly 40 percent of total agricultural value creation, indicating the major contribution of services and technological support to production efficiency.

The Israeli model also strongly emphasizes public-private partnership mechanisms. The Ministry of Agriculture, technology companies, research institutions, and farmers' associations operate in close cooperation. For instance, the MOP (Water Planning for Agriculture) program introduced an integrated electronic platform for water allocation, water pricing, and financing innovative technologies. This platform contributes not only to the efficient use of water resources, but also to increasing transparency, accountability, and coordination among stakeholders.

The Israeli experience in innovative agro-services is highly relevant for Uzbekistan, where issues such as water scarcity, land degradation, and adaptation to climate change are becoming increasingly important. In particular, the adaptation of Israeli practices related to drip irrigation systems, digital monitoring technologies, precision agriculture, and scientific advisory services could significantly improve resource efficiency, agricultural productivity, and environmental sustainability in Uzbekistan's agricultural sector (Table 1).

Table 1. Main areas of the Israeli agro-services system[4]

Direction	Innovative solution	Implementation mechanism	Result
Drip sugar	Netafim systems	Design, installation, service	Reduce water consumption by 30–50%

3 Аграрный сектор Израиля: когда песок продуктивнее чернозема. https://app.agro-online.com/69119/details/

4 Strawberries in the Desert: From drip irrigation to vertical gardens, Utah officials learn how Israel does more with less water. https://www.sltrib.com/news/2023/05/01/strawberries-desert-drip/

Water treatment	Shipping from recycled water	Filtering and monitoring services	Restoration of water resources, environmental sustainability
Climate monitoring	Meteorological stations and satellites	Mobile applications and consulting service	Harvest planning accuracy increases
Innovative green houses	Automated climate control	Service through agro-technoparks	Productivity increases 2–3 times

The Netherlands is a relatively small country with limited natural resources; however, after the United States, it ranks second in the world in terms of agricultural exports. One of the key factors behind this achievement is the high level of development of its innovative agro-services system and the widespread application of scientific and technological approaches in agriculture. The country has achieved remarkable efficiency in agricultural production through intensive farming methods, efficient resource utilization, digital management systems, and cluster-based production models.

In the Netherlands, the agro-industrial sector develops through close cooperation among research institutes, universities, technology companies, and farmers' associations. A prominent example is Wageningen University & Research, which not only conducts advanced scientific research but also provides farmers with consulting services and practical support for implementing innovative technologies. Around this institution, numerous agri-tech startups, innovation laboratories, and research centers operate, forming a highly integrated agricultural innovation ecosystem.

The main directions of innovative agro-services development in the Netherlands include the following:

- Closed greenhouse technologies – Modern greenhouse systems developed under the concept of "Greenhouse Horticulture" ensure maximum productivity with minimal resource consumption. These systems enable full control of climatic conditions, precise regulation of water and fertilizer use, and the application of energy-efficient technologies.
- Digital agriculture – Agro-service platforms based on artificial intelligence (AI), Big Data analytics, and digital monitoring systems allow farmers to forecast yields, identify pests and diseases, optimize resource use, and improve decision-making processes in real time.
- Vertical farming – In response to increasing urbanization and limited agricultural land, the Netherlands actively develops multi-level indoor farming systems within urban areas, thereby strengthening food security and improving land-use efficiency.

The Dutch agricultural model also widely applies public-private partnership (PPP) mechanisms. For example, the Greenports Netherlands platform provides an integrated logistics, marketing, technological, and consulting service network connecting farmers, technology suppliers, exporters, and research institutions. This platform not only improves the efficiency of the domestic agricultural market, but also simplifies access to international markets and enhances export competitiveness (Table 2).

Table 2. Main directions of the Dutch agri-services system[5]

Direction	Innovative solution	Implementation mechanism	Result
Agro-technoparks	«Food Valley» cluster	Scientific research and technology transfer	Growth in exports of innovative products
Digital technologies	Drones, GPS, IoT systems	through Agroservice centers	Productivity and resource efficiency increase
Greenhouses	LED, hydroponics, aeroponics	Large greenhouse complexes	Crop quality and export potential will increase
Sustainable services	Organic production technologies	Consulting and training	Environmentally sustainable production

Recently, Wageningen University & Research launched its Digital Innovation Hub (DIH), an online platform designed to support agribusiness companies in their digital transformation processes. Although digital technologies are rapidly expanding across the European Union, maintaining competitiveness in the global economy, creating new jobs, and ensuring social inclusiveness remain important priorities. In this regard, the European Commission initiated the "Digitalising European Industry" program, aimed at ensuring that all enterprises gain access to advanced digital innovations and modern technological solutions.

5 WUR Supports Digital Transformation with New Innovation Hub. https://www.seedworld.com/europe/2023/01/16/wur-supports-digital-transformation-with-new-innovation-hub/

Digital Innovation Hubs (DIHs) are considered an integral part of this initiative. Their primary objective is to help enterprises better understand how digital technologies can improve production processes, products, and services. Within this framework, WUR established a specialized digital platform dedicated to agribusiness development and innovation support.

DIHs operate as non-profit "one-stop-shop" centers and provide a wide range of services, including:

- offering companies opportunities to test innovative technologies in practice before making large-scale investments, thereby assessing their effectiveness and potential economic returns;
- organizing professional development and training programs, online courses, internships, and skills enhancement activities;
- assisting enterprises in attracting investments through feasibility studies, business plan preparation, incubation, and acceleration programs;
- creating innovation ecosystems and collaboration opportunities through networking platforms, brokerage services, and partnerships among businesses, researchers, and investors.

For example, when a company develops a robotic solution capable of accurately and cost-effectively spraying plant protection products in agricultural fields, WUR can provide specialized testing sites and experimental platforms for practical trials. In addition, the institution assists companies in finding financial resources for prototype development and supports the creation of sustainable and innovative business models.

The Dutch experience is highly relevant for Uzbekistan, particularly in areas such as maximizing productivity from limited land resources, developing high-tech greenhouse systems, implementing digital agricultural management systems, and expanding urban agriculture models. The introduction of such innovative agro-services could significantly improve resource efficiency, enhance productivity, strengthen food security, and accelerate the modernization of the agricultural sector in Uzbekistan.

CONCLUSIONS AND RECOMMENDATIONS

The research findings demonstrate that the introduction of green innovations into agricultural production and their effective management should be implemented through a phased and systematic approach. This process begins with creating favorable conditions for the development of new green agro-services aimed at resource conservation, reduction of environmental impacts, and ensuring sustainable agricultural production through environmentally oriented and innovation-based solutions.

At the next stage, particular importance should be given to attracting green investments and establishing effective financial support mechanisms for innovative agricultural projects. In this context, the organization of environmental and economic expertise for innovative solutions becomes essential in ensuring their sustainability, economic feasibility, and practical effectiveness. The final stage involves the formation and expansion of green infrastructure facilities through the introduction of environmentally friendly technologies, renewable energy sources, digital monitoring systems, and smart agricultural management tools.

As an effective management mechanism for ensuring the consistent implementation of these stages, the study proposes a model of digital agro-platforms supporting green innovations in agriculture. This model enables farms and agricultural enterprises to access environmentally friendly services through integrated online platforms, including the rental of modern agricultural equipment, procurement of organic seeds and biofertilizers, access to green financing instruments, sustainable marketing solutions, and "green logistics" services.

The implementation of such digital agro-platforms contributes to increasing the efficiency and speed of production processes, reducing territorial and organizational limitations, improving resource management, and lowering production costs. In addition, digital integration enhances transparency, facilitates technology transfer, and strengthens cooperation among farmers, research institutions, investors, and service providers.

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