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INTERNATIONAL APPROACHES TO LAND RESOURCE MANAGEMENT: LESSONS FOR SUSTAINABLE LAND USE

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МІЖНАРОДНІ ПІДХОДИ ДО УПРАВЛІННЯ ЗЕМЕЛЬНИМИ РЕСУРСАМИ: УРОКИ ДЛЯ СТАЛОГО ЗЕМЛЕКОРИСТУВАННЯ

The article examines the theoretical aspects of land resource management in the context of globalization challenges and the transition to a sustainable development model. It reveals the essence of the concepts of "land resources" and

“rational land use” in conjunction with the concepts of institutional support, digital transformation, and food security. The importance of soil potential, in particular black soil, as a key factor not only in national but also global food security is emphasized. International experience in land resource management is analyzed using the examples of the United States, China, India, and Ukraine. It was found that, despite different institutional models, legal regimes, and forms of ownership, there is a trend in these countries toward strengthening environmental control, digitizing cadastral systems, introducing practices to restore fertility, and strengthening the role of the state in the strategic regulation of land use. The author proposes a model of the relationship between land resources and the Sustainable Development Goals (SDGs). It is emphasized that the level of food security and the development of the agricultural economy depend on the qualitative and quantitative potential of soils (black soil, arable land, fertility indicators), which, in turn, determine the possibilities for achieving the SDGs in three key dimensions: economic, environmental, and social. This approach allows for the combination of economic efficiency in land use with environmental imperatives and social stability. Particular attention is paid to the analysis of current challenges. It has been proven that these problems highlight the need to introduce “green” technologies and agroecological practices, such as precision farming, the use of agricultural drones, the biologization of production, and the expansion of the organic sector. An integrated management concept has been developed, based on digitalization, transparency of cadastral processes, and increasing land value as an indicator of sustainability. The practical significance of the results obtained lies in the possibility of using the developed provisions to develop a state land policy strategy aimed at preserving soil fertility, increasing the efficiency of agricultural production, developing rural areas, and integrating Ukraine into global food chains. The proposed model can serve as a tool for assessing the impact of land potential on the achievement of SDGs and for improving management mechanisms at the state, community, and agribusiness levels.

У статті досліджено теоретичні аспекти управління земельними ресурсами в умовах глобалізаційних викликів та переходу до моделі сталого розвитку. Розкрито сутність понять «земельні ресурси» та «раціональне землекористування» у поєднанні з концепціями інституційного забезпечення, цифрової трансформації та продовольчої безпеки. Підкреслено значення ґрунтового потенціалу, зокрема чорноземів, як ключового фактору не лише національної, а й глобальної продовольчої безпеки. Проаналізовано міжнародний досвід управління земельними ресурсами на прикладі США, Китаю, Індії та України. Встановлено, що, незважаючи на різні інституційні моделі, правові режими та форми власності, в зазначених країнах простежується тенденція до посилення екологічного контролю, цифровізації кадастрових систем, впровадження практик відновлення родючості та посилення ролі держави у стратегічному регулюванні землекористування. Запропоновано авторську модель взаємозв'язку земельних ресурсів із Цілями сталого розвитку (ЦСР). Наголошено, що від якісного та кількісного потенціалу ґрунтів (чорноземи, рілля, показники родючості) залежать рівень продовольчої безпеки та розвиток аграрної економіки, які, в свою чергу, визначають можливості досягнення ЦСР у трьох ключових вимірах – економічному, екологічному та соціальному. Такий підхід дозволяє поєднати економічну ефективність землекористування з екологічними імперативами та соціальною стабільністю. Особливу увагу приділено аналізу сучасних викликів. Доведено, що наведені проблеми актуалізують потребу у впровадженні «зелених» технологій та агроекологічних практик, таких як точне землеробство, застосування агродронів, біологізація виробництва, розширення органічного сектору. Сформовано інтегровану концепцію управління, засновану на цифровізації, прозорості кадастрових процесів та підвищенні вартості землі як індикатора сталості. Практичне значення отриманих результатів полягає у можливості використання напрацьованих положень для розроблення стратегії державної земельної політики, спрямованої на збереження

родючості ґрунтів, підвищення ефективності агровиробництва, розвиток сільських територій та інтеграцію України у глобальні продовольчі ланцюги. Запропонована модель може слугувати інструментом для оцінки впливу земельного потенціалу на досягнення ЦСР та для удосконалення механізмів управління на рівні держави, громади та агробізнесу.

Keywords: *land resources, land resource management, rational land use, food security, sustainable development, sustainable development goals, green technologies, land use management, land market.*

Ключові слова: *земельні ресурси, управління земельними ресурсами, раціональне землекористування, продовольча безпека, сталий розвиток, цілі сталого розвитку, зелені технології, менеджмент землекористування, ринок землі.*

General statement of the problem and its connection with important scientific or practical tasks. The issue of rational land use is widely covered in international scientific research. In particular, the works of the FAO, OECD, and World Bank focus on global trends in soil degradation, the need to introduce environmentally friendly technologies, and digital tools for monitoring land use. Foreign scientists are studying land resource management models in the US, China, and India, which are based on a combination of state regulation and market mechanisms. Ukrainian scientists pay considerable attention to issues of soil fertility protection, land market transparency, improvement of cadastral systems, and digitization of management processes. At the same time, aspects of integrating sustainable development principles into land use practices at the farm level remain understudied, which makes further research in this area relevant.

Analysis of recent studies and publications. Scientific literature of recent decades widely covers the issue of rational use of land resources in global and national contexts. Studies by FAO, World Bank, and OECD focus on the

degradation of arable land, the growing risks of desertification, and the need to introduce green technologies in agriculture.

The current scientific debate on land resource management focuses on two interrelated dimensions: institutional support for effective land use in the context of market transformations and technological and environmental tools to ensure soil sustainability. Naumchuk V. V. provides a detailed analysis of global experience in institutional support for land resource management in the context of market changes and emphasizes the need to develop adaptive legal and financial mechanisms that would mitigate transformation risks and stimulate rational land use. The author stresses the importance of balancing market instruments (auctions, market consolidation) with state regulation measures to preserve fertility and prevent degradation [2].

The experience of EU countries, summarized by Skyba M. V. demonstrates the practical implementation of a combination of integrated policies: developed cadastral systems, mechanisms for targeted financing of land improvement and conservation measures, as well as strict environmental standards accompanied by instruments to support agricultural producers. European practice is representative of the formation of "composite" approaches, where market incentives are complemented by grant support for soil restoration measures and the introduction of precision farming technologies [3]. This experience is useful in adapting policies for countries with different natural and climatic conditions, including Ukraine.

The theoretical foundations of land use institutionalization are summarized in a monograph by Tretiak A. M. and co-authors [4]. The authors propose a systemic-political model that combines the regulatory, economic, and social dimensions of land management. Particular attention is paid to the mechanisms for coordinating institutional actors – the state, local communities, and the market – and the role of cross-border standards in harmonizing practices. The monograph provides a conceptual foundation for the development of national strategies that

reconcile local characteristics with international sustainable development requirements [4].

Makarova V. V. introduces an important practical indicator – the value of land as a measure of the sustainability of the agricultural land use system. The author demonstrates that economic assessments of land capital should take into account not only market prices, but also ecosystem services, long-term fertility, and the costs of restoring degraded areas. This methodology allows for the development of more comprehensive public policy instruments (tax, insurance, investment) for the conservation of black soil and other valuable soils [1].

At the same time, research in international environmental literature focuses on the limits of "land potential" and its connection to food security. Xiukang W. emphasizes the key role of assessing carrying capacity as a basis for planning sustainable production systems: soil resource management must take into account the limits of productivity recovery, water balance, and climate risks to ensure long-term productivity without soil depletion [9]. This position organically combines environmental and food imperatives, laying the scientific foundation for the model of the relationship between land resources and SDGs proposed in the article.

The agroecological perspective and empirical evidence of its effectiveness are highlighted in a global review by Kerr R. B. et al. The authors demonstrate that agroecological practices can contribute to increased food security and improved nutritional status of the population, especially with moderate use of intensification technologies and government support. At the same time, the paper highlights limitations – the need to adapt practices to local ecosystems and socio-economic contexts, and the need for long-term experimental research [7]. This is in line with our focus on "green technologies" as a tool for achieving SDGs 2, 12, 13, and 15.

Overall, the analysis of these publications provides several practical and theoretical conclusions for further research and policy: first, the importance of integrated institutional solutions – combining market mechanisms with state guarantees for the preservation of soil capital [2, 3, 4]. Second, the need for high-quality methods of assessing land value and carrying capacity to inform policy

decisions [1, 9]. Third, the promise and simultaneous complexity of the widespread application of agroecology and other green technologies – they require local adaptation and systemic support [7].

Formulation of the objectives of the article (task statement). The purpose of the study is to substantiate theoretical and methodological approaches and practical solutions for land resource management in the context of achieving the Sustainable Development Goals.

Summary of the main research material. Land resources are one of the key factors in the sustainable development of humanity, as they determine the possibilities for food production, ecosystem support, and economic stability. Land resources are an integral part of the natural environment, covering territorial space and soil cover, capable of providing ecological, economic, and social functions. They are simultaneously the material basis of economic activity, a key factor in food and energy security, and a carrier of ecosystem services. Unlike other resources, land is spatially limited and non-renewable, which makes its rational use and protection particularly valuable. It should be emphasized that qualitative and quantitative potential directly affects the ability of states to provide their populations with food and develop export potential.

Over the past 60 years, from 1963 to 2023, the area of agricultural land in the world has increased by only 16.55%, and the area of arable land by only 8.52% (Fig.1). These data indicate the limited nature of land resources and underscore the critical need for their effective management. Despite the growth of the world population and demand for food, the rate of expansion of agricultural areas remains relatively low, making the rational use of available land and the introduction of innovative and green technologies particularly relevant for ensuring food security and sustainable development. It should be emphasized that rational land use is a scientifically sound and economically viable system of land management that ensures an optimal combination of productive use of land with the preservation of its ecological balance and regenerative potential. It involves coordinating economic, social, and environmental goals, minimizing negative human impact on

soil, preventing degradation, and maintaining fertility. In today's world, rational land use is a tool for achieving the Sustainable Development Goals, as it combines economic efficiency, environmental safety, and social justice in the field of land resource management.

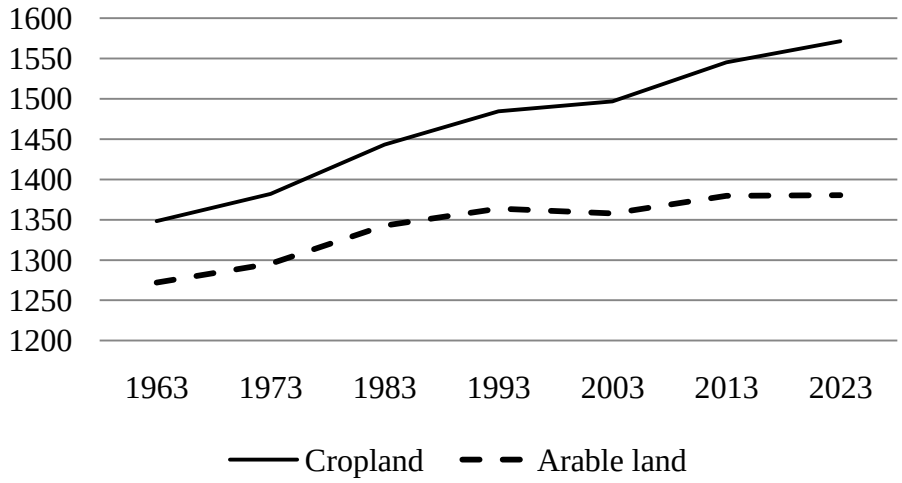

Fig. 1. World dynamics for agricultural and arable land areas, 1963-2023, million ha.

Source: compiled based on [6].

Given the limited availability of land resources and the need for their rational use, it is particularly important to analyze countries with large areas of arable land and different approaches to land resource management. According to FAOSTAT data, the largest areas of arable land are concentrated in the US and India, while China ranks fourth and Ukraine ninth (Fig. 2).

To examine land resources and their impact on food security, we selected four countries: the United States, India, China, and Ukraine. The United States and India are leading in terms of arable land area and the production of major agricultural crops, making them strategically significant for global food security. China, ranking fourth in terms of arable land area, stands out for its high level of agricultural intensification and technological innovation, which allows it to ensure food stability for its huge population. Ukraine, despite ranking ninth in terms of arable land area, has some of the most fertile soils in the world–black soil–and

significant grain export potential, making it an important player in the international food market. Thus, the selection of these countries allows us to explore a combination of different land use models, ranging from high-tech and intensive agriculture in China and the United States to resource-efficient and export-oriented agriculture in Ukraine. India represents a mixed land use model, combining traditional small-scale farming with the gradual introduction of modern technologies aimed at increasing productivity and rational use of natural resources.

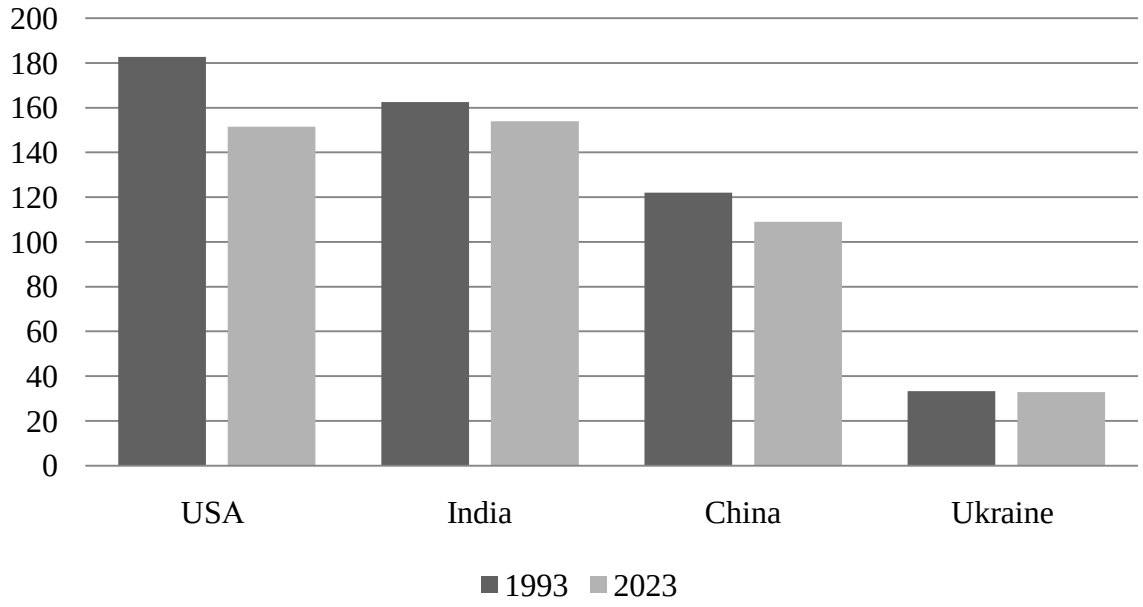

Fig. 2. Countries with the largest arable land area, 1993-2023, million ha.

Source: compiled based on [6].

Figure 2 shows the dynamics of changes in arable land area from 1993 to 2023 in countries with the largest agricultural land areas, namely the United States, India, China, and Ukraine.

In 1993, the United States was the leader in terms of arable land area with over 182 million hectares, but by 2023, this figure had decreased by approximately 31.12 million hectares. India, which had about 162.5 million hectares of arable land in 1993, saw a decrease of 8.7 million hectares in 2023. China showed a reduction in arable land from over 121.9 million hectares in 1993 to about 109 million hectares in 2023, which may be a consequence of urbanization and

industrialization. Ukraine has a significantly lower figure than the leading countries – about 32.92 million hectares in 2023.

It should be noted that over the past six decades, the global arable land area has grown at a very slow pace due to a number of complex factors. First, a significant portion of arable land is already in use, and opportunities for expanding agricultural areas are limited by natural conditions such as mountainous terrain, aridity, or swampiness. Second, competition for land between agriculture, urbanization, and industrial development is increasing, limiting the space for new arable land. The third factor is the tightening of environmental regulations and global attention to the conservation of natural ecosystems, which is encouraging many countries to stop clearing forests and grasslands. At the same time, arable land is increasing in some regions of Africa, Latin America, and Asia due to the development of new land, as well as the reclamation and restoration of degraded land, which allows areas that were previously unsuitable for economic use to be returned to cultivation. Thus, the slight increase in arable land reflects the balance between high demand for food and limited natural and socio-economic resources, as well as the growing need to integrate sustainable land use principles on a global scale.

It should be noted that the United States has one of the most advanced land management systems. Fertile black soil is concentrated in the states of Iowa, Illinois, Nebraska, and Kansas, ensuring high yields of corn, soybeans, and wheat. Modern agricultural technologies, irrigation systems, and digital farm management allow for consistently high productivity.

China has significant areas of arable land, concentrated in the Yangtze and Yellow River basins. Although black soils are found mainly in the northeastern provinces (Heilongjiang, Jilin, Liaoning), their fertility is under pressure due to intensive use. China is actively implementing soil restoration and crop rotation optimization programs, which are important factors in ensuring food security for the world's most populous country.

India is distinguished by its large areas of arable land, especially in the states of Punjab, Uttar Pradesh, and Haryana. Although black soil (regur) is found only in certain regions (the states of Maharashtra, Madhya Pradesh, and Gujarat), it is extremely valuable for growing cotton, cereals, and legumes. India's agriculture is heavily dependent on monsoon rains, which makes water management systems important in the context of food security.

Ukraine is known for its unique black soil, which covers about 60% of the country's agricultural land. It has high natural fertility and is the basis for growing wheat, corn, sunflowers, and rapeseed. Ukraine is one of the world's exporters of grains and oilseeds, making it an important part of the global food system. Land management here focuses on improving land use efficiency, introducing modern agricultural technologies, and preserving soil fertility.

In 2022, the share of black soil in the land fund structure was 57.01% in Ukraine, 5.3% in China, and 3.28% in the United States [5]. In India, black soil (regur) occupies a small part of the territory. This difference is due to natural and climatic conditions, geological history, and historically formed areas of fertile land.

Thus, land resources remain a key factor in food security. Effective management of these resources, rational use of black soil, and the introduction of innovative technologies in agriculture are the key to stable food supply for the population and sustainable development of the agricultural sector on a global scale.

At the same time, between 2015 and 2019, at least 100 million hectares of healthy and productive land were degraded each year, affecting food and water security worldwide. This loss is equivalent to an area twice the size of Greenland and affects the lives of 1.3 billion people who are estimated to be directly affected by land degradation [8].

At the same time, practical approaches to land management vary significantly from country to country, due to historical traditions, legal systems, levels of government control, and national priorities for sustainable development. This necessitates a comparative analysis of land use models in different countries to identify best practices and determine how they can be adapted to the Ukrainian

context. Table 1 shows the characteristics of land resource management in the United States, India, China, and Ukraine.

The data in Table 1 show differences in land ownership forms, levels of governance, control methods, and specific characteristics of each country. The United States is characterized by a priority on private ownership, decentralized governance, and widespread use of monitoring technologies. Here, land is subject to open sale and purchase, which ensures a high level of market liquidity and the efficient use of land for the production of major agricultural crops.

Table 1. Comparative characteristics of land resource management systems in the United States, India, China, and Ukraine

Country	Form of ownership	Main level of management	Control methods	Features
USA	Private, public.	Federal level, state and local authorities.	Zoning of territories, compliance with environmental standards, and use of geographic information systems (GIS).	Priority of private property; developed system of technological monitoring; state financial support for the agricultural sector through subsidies.
India	State and municipal (public).	Central and regional authorities, local communities.	Cadastral registration, registration of property rights, state irrigation and land reclamation programs.	Combination of state regulation with traditional community rights; comprehensive measures to combat soil degradation and conserve water resources.
China	State and collective.	Central government and regional administrations.	Control of land distribution, use of geographic information systems (GIS) and satellite monitoring.	Strict regulation of land use changes; centralized management; large-scale introduction of high-yield agricultural technologies.
Ukraine	Public and private (market).	State Service for Geodesy, Cartography and Cadastre, local government bodies.	Maintenance of the state land cadastre, land auctions, digital management systems, remote sensing of the Earth (RSE).	Combination of market mechanisms with state control; priority of soil fertility preservation and restoration; introduction of digital monitoring technologies.

Source: compiled by the author.

India combines state regulation and traditional community rights, with an emphasis on land reclamation and combating soil degradation. The land market is characterized by a high level of fragmentation of ownership and limited liquidity: most transactions take place through leasing or transfer of use rights, which allows small farmers to access land resources.

In China, state and collective ownership remain in place, allowing for centralized control over land distribution and the introduction of modern agricultural technologies. Private purchase and sale of agricultural land is limited, and usage rights are transferred for long periods, ensuring state control over strategic land resources.

In Ukraine, where state and private ownership coexist, the key instruments are cadastral systems, auctions, and digital technologies aimed at ensuring transparency, stimulating investment, and restoring soil fertility. The land market, open to individuals and legal entities with certain restrictions, actively shapes prices and creates economic incentives for the rational use of arable land.

A comparative analysis shows that, despite differences in management models, all countries share a common desire to preserve soil resources and increase their efficient use. This aspect is particularly important for agrarian countries with a high proportion of arable land in their land fund structure. The rational use of arable land and black soil is a fundamental condition for ensuring food security. Highly productive soils allow for stable yields, which directly affects the amount of available food and the export potential of agrarian countries. However, the limited availability of fertile land and the threat of its degradation bring to the fore the introduction of modern technologies that support sustainable development.

These interrelationships are summarized in the model (Fig. 3), which demonstrates the key role of land resources in shaping food security, developing the agricultural economy, and achieving the Sustainable Development Goals. Figure 3 illustrates the logic of the interrelationship between key components: the qualitative and quantitative potential of land resources, including black soil, arable land, and soil fertility indicators, directly determines the level of food security and

the development of the agricultural economy. These elements, in turn, determine the possibilities for achieving the Sustainable Development Goals in three dimensions: economic, environmental, and social. Thus, the model emphasizes that effective land resource management is a fundamental condition for the balanced development of society and the reduction of global risks associated with soil degradation and food shortages.

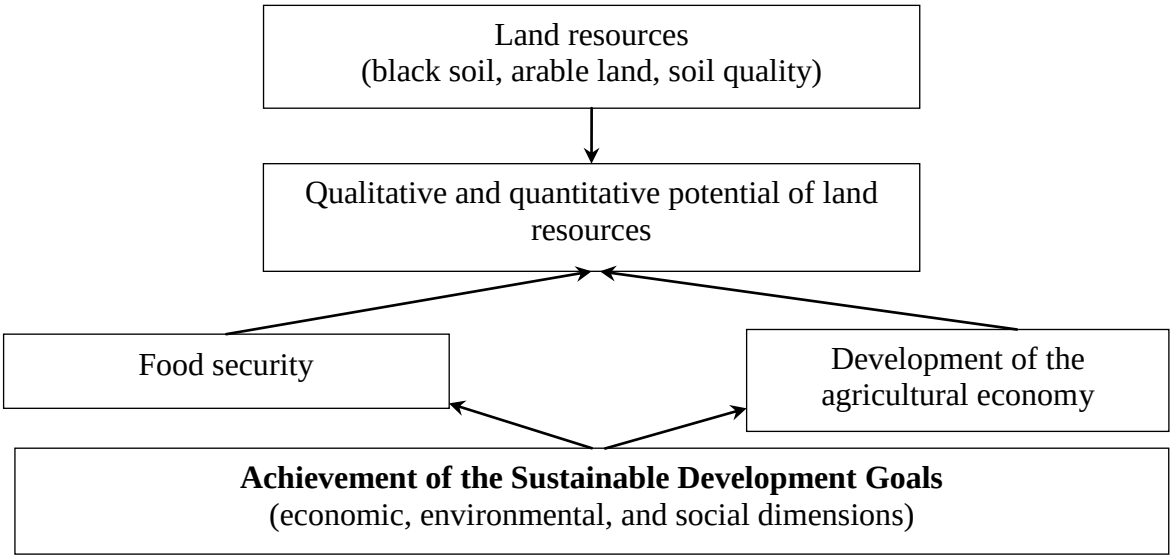

Fig. 3. Model of the relationship between land resources and SDGs
Source: compiled by the author.

At the same time, modern innovations are becoming an important tool for implementing this model. They are capable of ensuring more rational use of natural potential, reducing losses and negative impact on the environment. In this context, green technologies in agriculture, which combine economic efficiency with environmental sustainability, occupy a special place.

Green technologies in agriculture cover a wide range of innovative solutions aimed at increasing productivity while minimizing negative environmental impacts. These include precision farming using GPS and agricultural drones, soil and water monitoring systems, organic farming, restoration of degraded land, and the introduction of agroforestry systems. These technologies enable the efficient

use of available resources, optimize fertilizer and water use, reduce soil erosion, and support biodiversity.

In the context of the Sustainable Development Goals, green technologies provide synergy between economic efficiency and environmental sustainability. SDG 2 “Zero Hunger” emphasizes the need for stable food production, while SDG 12 “Responsible Consumption and Production” and SDG 15 “Life on Land” focus on preserving soil fertility, preventing land degradation, and supporting ecosystems. The introduction of green technologies allows countries with large areas of black soil, such as Ukraine, to maintain large-scale food production while preserving soil fertility. For countries with limited highly productive land, such as the United States, China, and India, green technologies are becoming critical to improving the efficiency and sustainability of agricultural production.

Thus, an approach that combines green technologies and sustainable development principles ensures food security, economic stability, and environmental sustainability. This forms the strategic basis for modern agriculture capable of meeting the needs of current and future generations. However, technological modernization alone is not enough to achieve these goals. Effective land management is of key importance. After all, land is the main production asset of an agricultural enterprise, and the success of the entire economic system depends on how rationally and balanced it is used. In this context, the model of agricultural enterprise land resource management based on SDG determinants, which allows combining economic performance with environmental responsibility and social orientation, is of particular importance (Fig. 4).

The central element of the model is land resources, the use and protection of which form the basis for the economic, social, and environmental sustainability of the enterprise. The model combines different levels of management: strategic, tactical, and operational, integrating economic, technological, and environmental solutions. Key determinants of CSR in the model include: efficient use of soil, preservation of soil fertility, introduction of innovative technologies, compliance with environmental standards, and social responsibility. The use of these

determinants allows for the optimization of production processes, ensuring sustainable yield growth, and increasing the economic efficiency of the farm. Thus, the model reflects a systematic approach to land resource management, combining the principles of sustainable development, modern control technologies, and strategic planning, which ensures long-term productivity and environmental safety of agricultural enterprises.

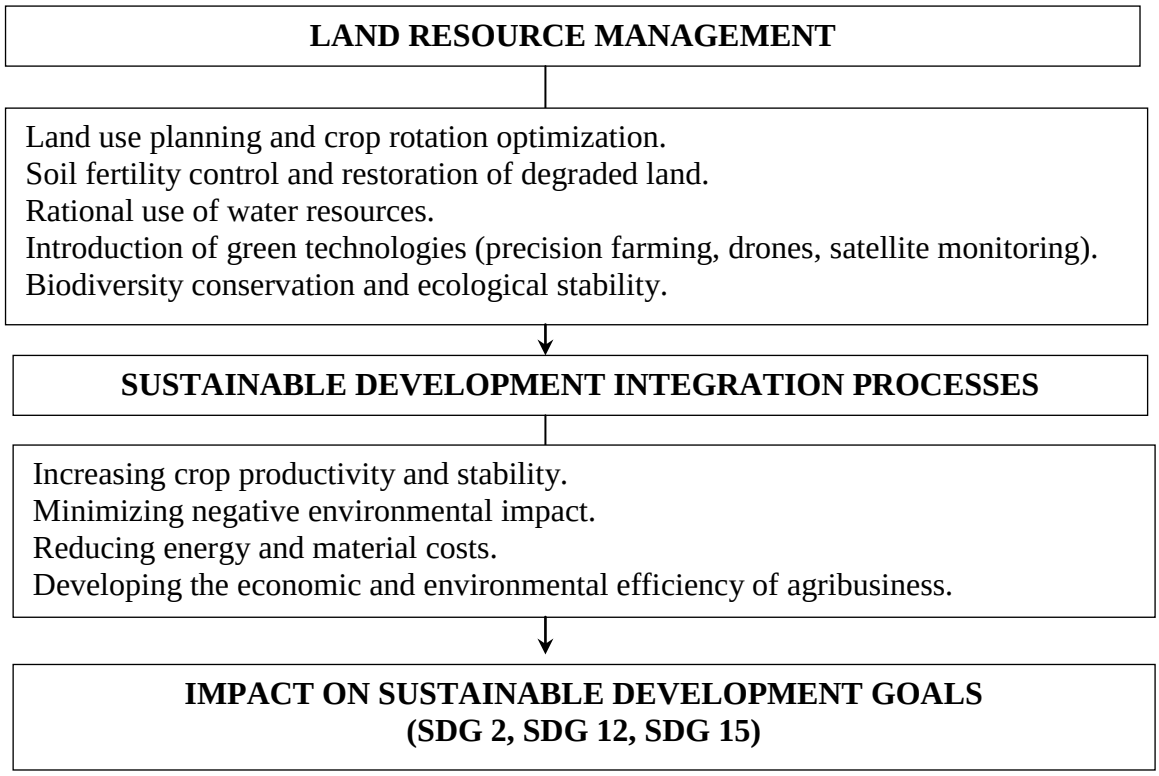

Fig. 4. Model of agricultural enterprise land resource management based on SDG determinants

Source: compiled by the author.

To implement effective land management in Ukraine, it is possible to draw on the experience of leading countries such as the United States, India, and China. The United States applies a comprehensive approach that takes into account the ecological capacity of land, the economic feasibility of its use, and institutional support. This approach ensures the balanced and sustainable development of agricultural and natural areas.

India demonstrates successful practices of joint forest management, where state authorities cooperate with local communities to preserve forest resources and provide the population with the necessary resources. In addition, the national agroforestry policy integrates tree cultivation, crop production, and livestock farming on the same plot of land, which increases agricultural productivity and sustainability.

China focuses on restoring degraded land and using innovative technologies. In particular, government programs encourage the cessation of soil erosion and the restoration of vegetation cover, while satellite monitoring allows for effective control of land conditions over large areas and planning for their rational use.

It is important for Ukraine to integrate these approaches. It is advisable to implement models of joint land management with the participation of local communities, use modern technologies for monitoring and planning land use, and support the restoration of degraded areas. Educating the population and raising awareness of the importance of sustainable land management will be an additional factor for success.

Applying these approaches can significantly improve the efficiency of land resource management in Ukraine and ensure their sustainable use, creating a basis for long-term agricultural productivity and environmental security.

Conclusions and prospects for further research in this area. The study has once again confirmed that land resources are a strategic factor for sustainable development, as they determine the potential for food production, the formation of export opportunities, and the maintenance of ecological balance. An analysis of global trends in agricultural land and arable land has shown that opportunities for expansion are limited and highlighted the need for more rational use of existing areas. A comparative analysis of land resource management systems in the United States, India, China, and Ukraine revealed different models of regulation, but what all countries have in common is the desire to preserve soil fertility and increase the efficiency of land use.

The proposed model of the relationship between land resources and SDGs has demonstrated that the qualitative and quantitative potential of land directly affects the level of food security and the development of the agricultural economy, and through them, the achievement of global sustainable development goals in economic, social, and environmental dimensions. An important tool for realizing this potential is the introduction of green technologies that combine innovation, resource efficiency, and environmental sustainability. They can ensure synergy between society's needs for stable food production and the need to preserve natural ecosystems.

Prospects for further research in this area lie in an in-depth study of the tools for digitalisation of land resource management and an assessment of the effectiveness of green technology implementation in different agroclimatic conditions. An important task for future research is also to analyze the possibilities of adapting international practices to Ukrainian realities, particularly in the context of restoring degraded lands, developing precision farming, and integrating the agricultural sector into the system of global Sustainable Development Goals.

Література

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