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EUROPEAN INTEGRATION OF LEGAL REGULATION IN AGRICULTURAL GREENING AND OF DIGITIZATION FOR SUSTAINABLE DEVELOPMENT

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ABSTRACT

Aim of the study

In light of international obligations and the pursuit of sustainable development, this article examines and identifies gaps in national legislation, while aiming to evaluate the degree of convergence with EU environmental and digital standards, and to formulate recommendations for harmonizing regulatory frameworks to support sustainable development.

Material and methods

An interdisciplinary methodology was applied, combining comparative legal analysis, systemic and historical-logical approaches, and case studies of key EU digital governance platforms. The analysis drew upon EU regulations, Ukrainian legislation, OECD and UNEP–FAO analytical frameworks, as well as scientific literature, to examine institutional alignment, technological infrastructure, and governance practices.

Results and conclusions

Findings reveal partial convergence between Ukraine's regulatory system and EU requirements. Key deficiencies include fragmented legislation, limited interoperability of agricultural data systems, weak institutional coordination, and insufficient support for small and medium-sized farms. Comparative analysis indicates that the EU's hybrid model, which integrates digital monitoring, environmental conditionality, and multi-level governance, provides structurally relevant lessons for Ukraine. The study identifies priority gaps in eco-scheme implementation, advisory systems, data governance, and cross-sectoral cooperation. Strengthening institutional capacity, establishing unified agri-environmental monitoring, enhancing data interoperability, and expanding support for SMEs are essential for effective alignment with EU agricultural and environmental policies.

Keywords: agricultural sector, European Union, greening, scientific and technical cooperation, Ukraine

INTRODUCTION

The rapid development of digital technologies at the beginning of the twenty-first century has significantly impacted virtually every aspect of public life, including the agricultural sector, which has historically been a crucial component of national economies. As it addresses several global challenges, including climate change, depletion of natural resources, soil degradation, loss of biodiversity, and growing demand for

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safe food products, the combination of digitization and greening of agricultural production has become one of the most significant global trends in sustainable development.

The implementation of precision agriculture, rational resource management, optimization of production processes, and reduction of negative environmental impact have become possible thanks to innovative solutions, including the Internet of Things, artificial intelligence, blockchain, satellite monitoring, and big data processing technologies. The creation of these processes is directly aligned with the UN Sustainable Development Goals and the objectives of the European Green Deal, which emphasize the need to conserve natural capital, adopt innovative food production methods, and transition to a climate-neutral economy. Given the processes of European integration, it is crucial to align Ukraine's agricultural policy with European standards.

The agrarian sector of Ukraine plays a strategic role, generating a substantial portion of the country's foreign exchange earnings, ensuring its food security, and creating employment opportunities in rural areas. In the field of sustainable agriculture, the importance of responsibilities for aligning national legislation with EU standards has increased since the signing of the Association Agreement with the EU and the country's designation as a candidate for membership. Articles 403–406 of the Association Agreement provide for the development of rural areas, the introduction of organic farming, environmentally friendly technologies, and creative solutions, as well as enhancing the competitiveness and attractiveness of the agricultural sector for investors.

Despite current successes, Ukraine's greening and digitization initiatives face significant challenges. These include the lack of affordable and adaptable solutions for small and medium-sized farms, the fragmentation and ambiguity of regulatory frameworks, the lack of practical real-world examples at the national level, and the insufficient integration of digital and "green" technologies into production processes. The effects of military operations pose additional obstacles to investment, modernization, and innovation, further complicating the situation. Under these circumstances, it is essential to conduct a thorough scientific analysis of the legal framework regulating the greening and digitization of Ukraine's agricultural sector, taking into account the State's international obligations, modern global problems, and the goals of sustainable development.

Several scientists have investigated this field. In particular, Saúlko (2024) analyzed the use of innovative technologies in the agricultural sector to monitor and optimize production. Metelenko et al. (2025a) explored the role of digital technologies in implementing green solutions, whereas Kryukova and Ihnatenko (2025) explored priorities for the modernization of fixed assets, taking into account sustainable development. Metelenko et al. (2025b) reviewed the synergies between digitization and eco-sustainability for regional development, and Sierov (2024) examined the impact of eco-innovation on sustainable agribusiness and explored ways to overcome barriers to its implementation. To identify opportunities for improving national policies in line with European standards and best practices, this work aims to assess the legal regulation of processes related to European integration.

This study aims at a methodical review of the legislative framework regulating 'greening' and digitization of agriculture in Ukraine within the framework of sustainable development and European integration. The purpose of this study is to identify gaps in the legal provisions for digital and 'green' reforms in the agricultural sector, to highlight contradictions between national and European legal frameworks, and to develop recommendations for harmonizing Ukrainian legislation with EU norms. A scientific problem is the lack of a thorough method for researching the institutional, legal, and practical aspects of integrating digital technologies and 'green' efforts in agriculture. A systematic legal analysis of these activities within the framework of European law has not been taken into account in previous publications, which mainly focused on economic or technological factors.

To achieve the research objective, the following research questions were developed: What fundamental ideas and guidelines for the legal regulation of digitization and 'greening' of the agricultural industry are enshrined in EU legislation? What institutional, legal, and practical obstacles prevent Ukraine from implementing these strategies? What aspects of the European experience can be included in the legislative

framework of Ukraine to promote the sustainable development of agriculture? To achieve Ukraine's course on European integration, the study aims not only to analyze the existing state of legal regulation but also to propose directions for improving legislation, taking into account the best practices of the EU.

MATERIALS AND METHODS

This study applies an interdisciplinary methodological framework designed to evaluate the legal regulation of agricultural greening and digitization in Ukraine within the context of European integration. The research is grounded in a diverse empirical base, including international institutional publications, EU regulations, Ukrainian legislation, and extensive scientific literature. The analysis draws on EU legal acts, Ukrainian regulatory documents, and scholarly and institutional publications. Special emphasis was placed on internationally recognized analytical sources such as the UNEP and FAO report Legislative Approaches to Sustainable Agriculture and Natural Resources Governance (2020), which provided criteria for evaluating sustainability-oriented legislation, stakeholder involvement, and environmental governance practices. Additionally, OECD reports on digital agricultural policy (2019, 2022) informed the assessment of digital readiness, data governance, innovation incentives, and the structural barriers shaping digital transformation in the agricultural sector.

The primary method used in the study is comparative legal analysis, which was applied to investigate the level of convergence between EU and Ukrainian legislation in environmental and digital domains. This method enabled the identification of gaps in legal alignment, inconsistencies in institutional responsibilities, and disparities in the practical implementation of environmental and digital standards. Comparative evaluation was supported by conceptual models and analytical criteria derived from OECD work, which offered guidance on policy design, monitoring efficiency, and the enabling conditions for technological integration. The UNEP and FAO framework further strengthened the ability to assess Ukrainian legislation against internationally accepted governance principles.

To complement the legal comparison, the research employs a systemic approach that conceptualizes agriculture as an interconnected socio-economic, technological, and ecological system. This approach made it possible to trace how legal norms, institutional capacities, environmental safeguards, and digital tools interact in practice, and to evaluate the implications of fragmented governance structures, limited interagency coordination, and uneven access to technology across different farming categories.

A historical-logical method was used to contextualize current EU agricultural governance by examining the evolution of the Common Agricultural Policy from its inception in 1962 to the post-2020 reforms, which emphasize environmental performance, digital monitoring, and multi-level governance. This perspective allowed the study to identify long-term structural factors behind the integration of environmental and digital dimensions into EU agricultural management, and to understand how these developments influence Ukraine's path toward harmonization.

The research also applies a case study method focused on key EU digital governance platforms, including Copernicus, the Farm Sustainability Tool (FaST), and the Farm Accountancy Data Network (FADN). These platforms were selected to illustrate how EU member states implement data-driven agricultural monitoring, integrate environmental conditionality with digital tools, and organize interactions between farmers, administrations, private actors, and research institutions. The case studies enabled a detailed evaluation of institutional models and technological infrastructures that could be meaningfully adapted to the Ukrainian context.

Finally, the study relies on generalization and analytical synthesis to integrate the insights derived from international reports, EU legislation, academic literature, and Ukrainian regulatory documents. This synthesis supported the development of a conceptual framework for assessing Ukraine's progress toward integration and guided the formulation of recommendations. Through this combination of methods, the research achieves a coherent and comprehensive assessment of the legal, institutional, and technological dimensions of agricultural greening and digitization, enabling the identification of systemic bottlenecks and the development of a hybrid integration model that connects regulatory harmonization with functional modernization.

RESULTS

The results of the study are presented in this part in four analytical blocks: 1) legal analysis; 2) technology analysis; 3) comparative analysis with the EU; and 4) political consequences for Ukraine. Three criteria are used in the comparison: institutional procedures, functional efficiency, and compliance with legislation.

Legal analysis: EU and Ukraine

The single agricultural policy has played a crucial role in the European Union's (EU) implementation of the results of the Industrial Revolution. Consolidating its agricultural policy as early as 1962, the EEC introduced careful planning, development, and coordination of the efforts of several interested parties. Through constant change over 60 years, this has guaranteed the sustainability and effectiveness of the policy. The common agricultural strategy gradually focused on the adaptability and diversity of agricultural production, ensuring food security, after three rounds of substantial adjustments. Additionally, issues related to rural development, including climate change mitigation, environmental conservation, and agricultural competitiveness, have been incorporated into the planning of the standard agricultural policy.

This illustrates how a European strategy that strikes a balance between performance and environmental responsibility by combining financial incentives with legislative instruments is coherent and methodical. Such a model emphasizes the need to combine financial and regulatory instruments to promote sustainable land use in Ukrainian conditions.

Then, starting in 2013, several regulatory acts were adopted under the Common Agricultural Policy aimed at promoting sustainable development and innovation in agriculture, supporting the digital transformation of agriculture and rural areas in the European Union (EU), and 24 EU countries also agreed on cooperation in the field of digital agriculture in 2019. The EU's modern data-based agricultural management system can be characterized as a hybrid management paradigm. A more open and inclusive governance model, one that links government, the market, and civil society at all levels, replaces formal, hierarchical policy-making. Due to their relative neutrality, the government and other stakeholders play a relatively active and valuable role in meta-management to resolve conflicts (Anisimova and Donets, 2022).

Analysis of EU regulations shows that the basis of modern agricultural policy is a combination of environmental and digital elements. By analyzing this experience, we can identify effective institutional processes that could be used in Ukraine to improve legal certainty, promote innovation and guarantee sustainable growth in the agricultural sector.

It is not clear how the different levels of EU government will be responsible for the information flows currently being established and collected. The Agricultural Council is responsible for analyzing and processing agricultural data, creating global guidelines, and regulating markets. The Agricultural Council is also responsible for publishing the relevant information. Eurostat and the Agricultural Accounting Data Network (FADN) collect agricultural data through questionnaires in cooperation with third parties. Although the EU has full responsibility for the agricultural information process, the work of these institutions is complex and heterogeneous due to their multi-level management model, market reforms, loss of coordinating bodies, and limited ability to apply laws in different regions (Chen et al., 2024).

Technological analysis (platforms, data, actors)

It is worth noting that private players in the EU have played a crucial role in the digital transition since the 1990s. In Italy and Germany in 2017, there were 474 and 157 partner consulting firms, respectively, in 51 and 42 private institutions. These companies employ a supply chain management model to develop digital solutions for the agricultural industry, communicating directly with producers and offering services throughout the agricultural supply chain, from cultivation to marketing. These services include hardware systems, such as base monitoring stations, remote visualization tools, centralized management, and supporting software (including management modules, early warning modules, and cloud resource management technologies).

A comparative study shows that sustainable development and the effective execution of the digitization programme have been guaranteed by the participation of the private sector in the development of digital services in EU agriculture. digitization of the agricultural

industry in Ukraine is still mainly a state matter, which limits innovation, competition, and the speed of technology implementation.

By developing new agricultural technologies, technology companies that employ a market-oriented meta-management style increase the efficiency of agricultural production and reduce operating costs, enabling agriculture to transition from an inefficient raw material model to one that promotes sustainable development (Donets, 2019). Market participants, often motivated by material interests, develop a software package to collect information from farmers within the business firm model, supporting the transformation of agriculture through digital technology services in terms of information creation and collection. Additionally, software is available to enable European farmers to automate and streamline the subsidy application process (OECD, 2022).

Technology and commercial firms that engage in scientific and technological cooperation with governments and research institutes to develop an autonomous platform are participants in the EU market in terms of information analysis and application. For example, Food Valley NL is a separate platform for innovation and reform of the global food system (Dayıoğlu and Turker, 2021). Food Valley is developing an intelligent data system that includes all relevant and important information, trends, and achievements. Also included is a list of all parties involved in the EU's agricultural industry, from investors to entrepreneurs. However, the large number of market participants has made it more competitive for service providers that offer a wide range of services, which affects the cost of farmers' access to IT services (Sharapova et al., 2021).

This illustration shows that the EU's digital transformation is guaranteed not only by the existence of a legal framework, but also by effective cooperation between businesses, academic institutions and public authorities. It follows that in order to implement achievements in the agricultural sector, Ukraine must create a multi-level system of cooperation.

As a result, the primary function of farmers' associations is to serve as a liaison between the government and farmers, while also protecting their common interests. However, farm groups are also real executive bodies of strategic consulting at the national or regional level, often actively advising the state. On the one hand, they can disseminate information to all their members via the Internet, association publications, and telephone calls (UNEP and FAO, 2020).

For example, farming groups are the leading providers of scientific and technical innovation services to the populations of Austria, Belgium, Denmark, Finland, France, Lithuania, Portugal, Slovenia, Spain, and Sweden. Farm cooperatives can help farmers enhance their knowledge of digital technology, increase their proficiency in science, technology, and business management, and improve their capacity for innovation, democracy, and teamwork (Zeng et al., 2024). The European Union has several scientific and technical cooperation projects (the largest of which are Copernicus and FaST) offering technical assistance to farmers, Member States' paying agencies, agricultural consultants, and digital solution developers to help them become more qualified in the various fields of agriculture, the environment, and sustainable development (Donets, 2021).

For example, the European Union's space programme includes the Copernicus platform, which is dedicated to Earth observation and conducts research on the planet and its environment for the benefit of all Europeans. It provides information services based on in situ (non-space) Earth observation data and satellite observations. FaST, another Copernicus-based platform, helps improve crop management models, optimize daily operations, and improve cost-effectiveness while preserving the environment (OECD, 2019).

It also facilitates easier communication between farmers and other institutions about their crop history and the crop programs implemented across Europe (Abdulai, 2022). The FaST platform also helps in the following: carrying out environmental monitoring of agricultural land; improving two-way communication with farmers; computerizing agriculture; simplifying work processes; developing appropriate standards; achieving economies of scale; providing basic data; communicating directly with farmers to provide services; providing quick access to agricultural data, which helps analyze the current state of agricultural development and thus shape policy; using value-added services provided by commercial service providers to farmers; and contributing to the expansion of the market segment for small farms (Diachynska, 2024).

Comparative analysis with the EU (criteria-based)

Greening and digitization are closely related in the European Union's agricultural sector integration processes, as evidenced by the new Common Agricultural Policy (2023–2027). At least 25% of direct payments to farmers under the CAP are used to implement eco-schemes, and the European Commission reports that more than EUR 8.5 billion is spent each year on innovation, digital solutions, and 'precision farming'. Applications such as Copernicus and FaST ensure the seamless integration of ground and satellite data into production processes, enabling farms to operate more efficiently while reducing their environmental impact (MacPherson et al., 2022).

Comparing the conditions of Ukrainian production, where similar data integration tools (such as the DAR platform) are just beginning to be developed, full-fledged agroecological monitoring is still missing. This underlines the importance of modifying European standards in line with the country's information infrastructure. Three criteria were used in the comparative analysis: institutional, legal and functional. As indicated below, Ukraine demonstrates a partial approximation to EU practice (Table 1).

In addition, the 'Horizon Europe' program provides funding for dozens of sustainable agriculture initiatives in fields such as biotechnology, water management, and robotics. This comprehensive strategy provides EU candidate countries, including Ukraine, with a basic framework for reforming legislation, implementing advanced technologies, and developing rural regions in line with European sustainable development criteria (Petrova, 2023). Regarding Ukraine, it is essential to acknowledge the potential of technical solutions that have been developed and implemented for the agricultural sector. However, it should be stressed that modern technological solutions are not coordinated, and therefore they fail to provide all market participants with clear information and a single tool for information decision-making that would improve the sector's productivity and encourage the creation of safer, more efficient, and sustainable production models, and provide important Internet resources for the idea of supporting sustainable agricultural growth.

Digitization guarantees the following within the framework of sustainable development: increasing the efficiency and profitability of production without harming ecosystems; reducing emissions and chemical loads on the environment; rational use of natural resources (water, fertilizers and energy); transparency and traceability of agricultural chains thanks to digital monitoring; as well as increasing resilience to climate change thanks to risk forecasting (Tomashuk et al., 2024).

As part of the digital transformation of the agricultural industry to implement green technologies, important digital tools are emphasized. All this demonstrates that digitization is a strategic tool for the ecological reorganization of the agricultural sector in the face of global problems, as well as a kind of technical modernization. In addition to reducing environmental impact, these digital technologies help the

Table 1. EU–Ukraine analysis

Criterion	EU practice	Ukraine	Evaluation	Key gap
Legal framework	CAP 2023–2027 (eco-schemes, conditionality)	Fragmented and partially implemented	Partial	Create unified eco-scheme framework
Institutional mechanisms	Clusters, DIH, advisory networks	Weakly institutionalized	Partial	Strengthen advisory system, formalize clusters
Data and monitoring	Copernicus, FaST, FADN (integrated loop)	DAR – limited interoperability	Partial	Introduce national data standards and monitoring
Private sector role	Competitive digital providers	State-dominated model	Partial	Open regulated data access to private players

agricultural sector, which is the basis of sustainable growth, to maintain social stability and economic efficiency. With these technologies, we can reduce greenhouse gas emissions, protect natural resources, adapt the agricultural industry to climate change, and create a new, ethical, environmentally conscious, and commercially viable production culture. This is especially important for Ukraine, which requires innovative solutions for post-war recovery and integration into the European sustainable development sector, while maintaining its significant agricultural potential (Tymoshenko et al., 2022; Mazur, 2025).

Their use enables you to integrate environmentally friendly methods with innovation, aligning with the European 'green course' and the ideals of sustainable development. The implementation of green technologies is especially relevant for Ukraine, which has significant agricultural potential, but also urgently needs environmental restoration due to military actions. A crucial component of the country's post-war environmental and social recovery, as well as its economic recovery, is the adoption of environmentally friendly farming methods. Let us examine the primary categories of green technologies employed in agriculture. Green technologies enhance product quality, conserve resources, minimize environmental impact, and support the sustainable development of rural communities (Ostapenko et al., 2024).

Thanks to modern green technologies, it is now possible to grow crops in high-rise buildings, often in urban conditions. In addition to protecting the environment, green technologies in agriculture are an effective way to increase production, improve the quality of life for rural communities, adapt to climate change, and guarantee food security. Implementing these technologies will help create a sustainable agricultural industry that can address the challenges of the twenty-first century (Metelenko et al., 2025a).

The implementation of such methods is a strategic goal for Ukraine, which is working on post-war recovery and integration into the European space. In addition to enhancing agricultural competitiveness, focusing on environmentally sound, creative, and socially conscious agricultural production will help to create a new agricultural crop that is in balance with the environment. In this study, we consider the lessons that Ukraine can learn from this experience:

1. Creation of a state plan for the green transformation of agriculture.
2. Assistance in the exchange of resources and technology between agricultural cooperatives.
3. Financing sustainable management education initiatives for farmers.
4. Encouraging farmers to use sustainable energy sources.
5. Offering tax incentives or financial assistance to encourage the implementation of environmentally friendly solutions.

Governmental organizations, farmers, academic institutions, and other stakeholders must have access to such a platform.

Secondly, the decision-making process on agri-environmental policy must include digital technologies. It is recommended to utilize methods of artificial intelligence, machine learning, and geoinformation systems (GIS) to model agroecosystems, identify environmental hazards, and predict the consequences of management decisions (Kryukova and Ihnatenko, 2025). Establishing a legislative structure to monitor the use of these technologies, while considering security and ethical implications, is equally important.

Thirdly, farmers and civil servants involved in agriculture and the environment should be more digitally literate and encouraged to pursue digital education. It is crucial to implement training, certifications, and educational programs focused on the use of digital tools for environmental planning, impact assessment, and monitoring.

Fourthly, small and medium-sized farms must receive financial and technical assistance when implementing digital technologies. Government grants, subsidies, initiatives for cooperation with private businesses, and consulting services can be used to implement this.

Last but not least, the adoption of digital technologies must be supported by continuous assessment of policy effectiveness, adjustments to emerging issues, and public involvement in the decision-making process. The openness, credibility, and viability of agri-environmental policies will increase through the participation of stakeholders in the digital transformation process (Metelenko et al., 2025b). A strategically important path to achieving sustainable agricultural growth, conserving natural resources, and effective

environmental risk management is the integration of digital technologies into national agrarian and environmental policies. The basis for creating an adaptive, flexible, and successful policy is the implementation of digital infrastructure, the use of analytical tools and artificial intelligence, the growth of digital literacy, and state support for innovation.

Through a methodical approach to digitization, it will be possible to improve environmental safety, promote adaptation to climate change, and increase the global competitiveness of the agricultural industry. Adaptation of the provisions of the EU Common Agricultural Policy, particularly those related to digital and environmental standards, to national legislation is a crucial component of Ukraine's path to European integration. The establishment of a national agricultural data platform, integrated and compatible with European systems, in particular Copernicus, FaST and the Agricultural Accounting Data Network, the implementation of uniform agri-environmental monitoring standards and integration into joint European research initiatives such as Horizon Europe and the Digital Europe Programme, are among the top priorities in this respect (Saúlko, 2024).

Thus, the success of digitization and 'greening' of the agricultural industry depends on the complexity of regulation: the simultaneous development of the legal framework, financial incentives and digital infrastructure, according to the results of a study of EU legal and organizational models. The Common Agricultural Policy (CAP) has been only partially implemented in Ukraine, especially with regard to eco-schemes and monitoring systems, which requires improved regulatory consistency with European regulations.

Policy implications for Ukraine

Based on comparative results, the following political goals are proposed for Ukraine. Participation in European initiatives provides Ukraine with access to financial instruments, technical expertise, and innovative networks that accelerate the country's digital and green transformation. However, the success of this cooperation will determine the country's ability to create an internal institutional and legal structure in accordance with EU norms. Therefore, the main objectives of national reforms should be to support data interoperability, promote inclusive innovation, and strengthen regulatory coherence. Policy priorities are as follows:

1. To ensure compliance with the principles of the Common Agricultural Policy (CAP) by establishing a single system of eco-schemes related to agricultural payments and quantitative indicators of environmental performance;
2. To ensure compatibility between the Ukrainian DAR platform and European systems such as Copernicus and the Agricultural Accounting Data Network (FADN), national data standards and mandatory APIs should be implemented;
3. To promote responsible innovation and competition, standard agreements on data access and protection should be established, and a regulatory 'sandbox' should be established for private companies providing agro-digital services;
4. To establish public-private partnerships with well-defined missions, funding structures, and performance indicators to institutionalize agricultural clusters and digital innovation centres (CCIs);
5. To provide sustainable financial incentives for small and medium-sized farms, such as tax incentives for sustainable development, co-financing of precision farming technologies, and digital service coupons;
6. To establish an end-to-end tracking system that links agricultural payments, policy decision-making, and data collection to guarantee accountability, transparency, and evidence-based monitoring. Thanks to the implementation of these political decisions, Ukraine will be able to move from disparate green and digital projects to a comprehensive agricultural management system that meets European requirements. Such a system will enhance institutional capacity, foster innovation, promote sustainable development, and accelerate Ukraine's integration into European agricultural and environmental policies.

DISCUSSION

The study's results are interpreted in the context of sustainable governance and the philosophy of European integration. The aim is to critically assess how a convincing national plan for the digitization and greening of agriculture can address the stated legis-

lative, institutional, and technological shortcomings. Fragmentation of institutions, laws, and data flows continues to be a significant obstacle to digital and environmental convergence in Ukrainian agriculture, as shown in the comparison matrix in the 'Results' section. This fragmentation means that Ukraine continues to use the 'paradigm of reactive control', in which laws do not stimulate technological progress, but instead follow it. This strategy limits the State's ability to anticipate threats and develop systemic resilience in line with EU requirements.

The results suggest the effectiveness of an interdisciplinary approach that integrates legal, economic, and environmental research. The approach of comparative legal regulation enabled the identification of structural differences between Ukraine's legislation and the EU's, and the analysis of strategic documents and policies allowed for the determination of areas most suitable for adaptation. The best practices of legal aid in the field of digitization and 'greening' of the agricultural industry can be summarized thanks to the systematization of scientific sources. At the same time, the study demonstrated that regulatory inertia is the result of a formal translation of EU legislation without proper modification of its implementation procedures. This highlights the need to transition from 'paper' harmonization to effective convergence, focusing on achieving quantitative results, increasing institutional responsibility, and enhancing monitoring efficiency.

Since the digitization process is at a basic level, farmers exchange data with the Government and businesses at their discretion, and since data from consumers and agri-food companies have minimal impact on agricultural policy, we believe that Ukraine is characterized by a scenario of 'Easy digitization'. There are disparities in the adoption of technology and digital literacy. The use of digital technologies and digital literacy is extreme among agricultural holdings. However, the level of digital literacy and technology use among micro, small, and medium-sized farms (MSMEs) is low. It is worth noting that the launch of the DAR digital platform in 2022 contributed to the increase in data exchange.

The results of the study indicate the growth of the 'double speed' model of digitization, in which small farms remain outside digital processes, while large agricultural firms benefit from the use of modern technological solutions. Such digital inequalities will continue to hamper equitable growth and sustainable development in the agricultural sector in the absence of appropriate regulatory incentives and training initiatives. Ukraine is only at the beginning of the digital transformation of agriculture, according to comparison with European practices. Structural differences between data management models in the EU and Ukraine, as well as the main institutional obstacles to the successful integration of digital solutions into the national agricultural policy, were identified using comparative legal and analytical methods.

However, farmers only provide information when they are interested in specific award programmes for which they can apply. This means that political issues (grant programs) affect data exchange. In our view, the Government should consider the challenge of facilitating data exchange among all market actors, as this has the potential to enhance the efficiency of the digitization process in the agricultural sector. That is, farmers, the Government, traders, producers, consumers, and agrotechnological companies must be involved in the process of digitizing the agricultural industry (Sierov, 2024).

This suggests that players in the agricultural market have little incentive to communicate digitally with government, which limits the efficiency of data transmission, unlike in EU countries where digitization is encouraged both monetary and regulatory. It is important to introduce legal safeguards and incentives for farmers to participate in digital initiatives in order to address this issue.

Development of digital platforms, electronic management and service provision, agricultural consulting services, digital financial services, collection and exchange of information (both ways), as well as the creation of a digital feedback system from farmers to the Government to establish direct communication, are all examples of how relations between farmers and the Government can be digitally transformed. The digital revolution in the agricultural industry has dramatically enhanced the interaction between farmers and agrotechnological enterprises. Digital farm management systems, the production and use of precision farming tools, digital trading platforms and e-commerce platforms, agricultural information databases, education

and training, and data-driven analytics are key components of their digital interoperability.

Comparative studies show that EU countries take a multi-level management approach that combines decentralized innovation assistance with centralized data management rules. However, there is still a lack of cooperation between ministries, digital agencies and agricultural organizations in Ukraine, which reduces accountability and management efficiency. Following the example of EU countries, where digital platforms serve as both consultative and control mechanisms, the digitization of the agricultural sector should be seen not only as a technological advance, but also as a legal management tool guaranteeing accountability, transparency and sustainable development.

We can highlight the following important components of digital interaction between farmers and food traders/producers within the framework of the digital transformation of the agricultural sector: supply chain management; quality control and traceability of agricultural products; access to efficient logistics and supply solutions; control over certification and compliance with regulatory requirements; real-time market prices for products; and encouragement of cooperation and partnership (Diachynska, 2024).

As the agricultural industry evolves, noticeable changes are also occurring in the ways farmers and customers interact. Online markets and direct sales, consumer engagement and training, home delivery, access to feedback and comments on agricultural products, and virtual agricultural tours are the main components of digital contact between farmers and customers. The creation and development of a reliable digitization system are vital, given the complexity and diversity of the participants in the digital transformation process of the agricultural sector. To ensure the effective interaction of participants, the state must establish the necessary foundation, encourage the digitization of all involved parties, and promote the development of a cooperative network.

Understanding how farmers can integrate digital technologies into their operations is crucial because it is the primary focus of the digital transformation in the agricultural sector. The use of a farm management system, the digitization of data collection and processing procedures, the utilization of data-driven agricultural equipment, and the provision of decision support are the primary ways of digitizing agricultural production. Farmers will be able to collect important data, evaluate it for helpful insights, and use data-driven solutions to improve agricultural practices and achieve their goals, leveraging a combination of these tools.

The digital transformation of an individual agricultural producer can be built based on farm management systems (ERPs). The use of these tools will ensure the creation of a centralized platform to control various aspects of agricultural activity, such as labor resources, inventories, and financial administration. Farmers will be able to make informed decisions and see their farm performance holistically. To ensure a seamless flow of data and analysis throughout the farm, farmers can integrate ERP with other digital solutions as they move towards digitization, such as data collection, data-driven equipment, and decision support tools.

In digital agriculture, data collection solutions encompass the gathering of various types of information on crops, soil, weather, and other field variables. These solutions collect valuable data that can be used to make informed decisions on the farm, utilizing a range of tools and technologies, including yield monitors, soil sensors, and remote sensing. Farmers can study the collected data and make informed decisions with the help of decision-making tools. To identify patterns, trends, and areas for improvement, these systems utilize visualizations, including yield maps, soil maps, weed and pest maps, and yield maps.

In addition, solution support systems can utilize biophysical, machine learning, and artificial intelligence models to predict weather, pest, and disease outbreaks, as well as yields. Precision farming technologies that maximize agricultural operations using collected data and decision systems analytics are a significant focus of data-driven agricultural decisions. These solutions include automated section management, variable-rate irrigation, fertilizers, planting and pesticide applications, and control systems. Farmers can enhance field efficiency, minimize waste, and improve the overall sustainability and productivity of their farms by utilizing these technologies. Farmers can reduce risks, manage their stocks, and improve production processes by utilizing a range of digital agricultural technologies.

The study found that fragmented regulation, low digital literacy of farmers, and limited access to inno-

vation finance are the three main barriers to the implementation of European standards in local practice. The strengthening of legal incentives for small farms and the establishment of a holistic agro-ecological monitoring system were two important reform themes that can be outlined through analytical and comparative legal methodologies. The results obtained indicate the feasibility of implementing a hybrid regulatory model that combines vertical coordination (data and standards management) with horizontal initiatives (innovation and local adaptation).

The hybrid model therefore conceptualizes integration as a dual process in which normative convergence and practical capacity-building evolve in parallel and reinforce each other. Legal reforms are directly supported by operational mechanisms such as digital platforms, advisory services, monitoring tools, and cooperative networks. This allows the regulatory system to function even before full harmonization is achieved, reducing implementation gaps and accelerating institutional learning. In practical terms, the model consists of two interconnected dimensions:

- Vertical (regulatory) integration, which includes the approximation of Ukrainian laws to EU environmental and digital standards, adoption of eco-schemes, establishment of legal requirements for monitoring and reporting, and creation of unified data standards compatible with European systems such as Copernicus, FaST, and FADN.
- Horizontal (functional) integration, which includes strengthening advisory institutions, establishing innovation clusters, supporting private digital service providers, increasing digital literacy among farmers, and developing interoperable data infrastructures that enable real-time monitoring and policy evaluation.

The combination of these dimensions forms a regulatory ecosystem in which new legal norms are not isolated textual changes but are anchored in operational structures capable of ensuring their implementation. For a country such as Ukraine, facing the constraints of post-war recovery and structural imbalances in the agricultural sector, this approach reduces delays between legislative adoption and real-world enforcement, enhances institutional resilience, and promotes equitable access to innovation across farms of different sizes.

In addition to new opportunities, the digital transformation of the agricultural sector also presents obstacles and constraints that must be considered. Lack of funding is the most significant challenge facing Ukraine's agricultural industry. Due to the severe damage to the agricultural sector, logistical problems, low domestic prices for agricultural products, and the sharp rise in the cost of seeds, fuel, fertilizers, and other inputs needed to produce agricultural products, the war has significantly exacerbated the problem of financial resource scarcity (Diachynska, 2024).

Additional obstacles to achieving the set goals may also arise from standardization and various regulatory constraints. Agricultural workers may have concerns or even oppose the need to make substantial changes to the current way of working. Regulations on privacy and personal data protection may also hinder the digital transformation of specific farm management procedures. Integrating data of varying quality, addressing issues related to accountability, transparency, and oversight can pose some difficulties. So can recognizing data limitations, as well as the limitations of models and algorithms.

In general, the study's results indicate a shift in the management of Ukraine's agricultural sector from reactive adaptation to proactive integration. It is essential to prioritize institutional coherence, legal predictability, and quantifiable environmental outcomes to ensure sustainable digital and ecological convergence. The proposed hybrid integration paradigm, which combines functional improvements with legal harmonization, makes the study unique. While emphasizing institutional adaptation, it combines two previously separate dimensions: technology modernization and regulatory convergence. This idea presents a fresh perspective on the transformation of Ukraine's agricultural industry, highlighting the importance of sustainability and dynamic management capabilities, in addition to formal compliance with EU standards.

CONCLUSION

The study demonstrated that European integration not only establishes a paradigm of multi-level management, where digitization and greening function as mutually reinforcing aspects of sustainable development, but also influences the strategic modernization of

Ukraine's agricultural industry. The results of the comparison demonstrated that, for effective convergence, a shift from declarative alignment with EU standards to quantifiable integration through institutional capacity, transparent data systems, and compliance with legislative processes is necessary. The applied interdisciplinary approach provides a deep understanding of the problem, and we have been able to delineate the normative, institutional, and functional levels of management through the application of comparative and analytical methods. The results of the study indicate that the modernization of the agricultural industry is feasible only when environmental and digital concepts are integrated into a unified strategy for sustainable development.

By proposing the idea of a hybrid integration system that combines institutional innovation with the harmonization of legislation in the field of digital and green transitions, this article makes a new contribution. Our study integrates these elements through a comparative legal analysis of EU and Ukrainian practice, unlike previous studies that considered them independently. This method enables a more detailed understanding of how regulatory convergence can enhance policy coherence and sustainable management, and by doing so, it can lead to practical consequences. As a result of comparative legal and institutional analyses, targeted policy recommendations were developed focusing on data compatibility, harmonization of regulations, and assistance to small and medium-sized farms. These proposals translate analytical results into practical legislative measures. The establishment of a network of digital innovation centers, the harmonization of legislation with EU environmental and digital standards, the development of an integrated national agricultural data platform compatible with European systems, assistance to small and medium-sized farms in implementing digital solutions, increasing the digital literacy of farmers, and promoting the use of renewable energy sources are recommended.

This study has several shortcomings, despite its comprehensive interdisciplinary approach. The analysis did not empirically assess how the proposed mechanisms functioned at the microeconomic and farm management levels; instead, it relied mainly on legal and institutional sources. Future research should therefore focus on quantifying policy effectiveness, conducting case studies on the use of digital technologies by small and medium-sized farms, and studying management models that link technical and environmental standards. To identify both the universal and context-specific causes of sustainable agricultural transformation, further research may consider the applicability of the hybrid integration system in different transition economies. A convincing strategy that combines state aid, scientific advances, commercial developments, and active participation by farmers is therefore essential for the sustainable growth of the agricultural sector. In addition to improving productivity and environmental safety, the combination of digitization and greening fosters a new management culture founded on accountability, flexibility, and evidence-based practices.

REFERENCES

Abdulai, A.R. (2022). A new green revolution (GR) or neoliberal entrenchment in agri-food systems? Exploring narratives around digital agriculture, food systems, and development in sub-Sahara Africa. The Journal of Development Studies, 58(8), 1588–1604. https://doi.org/10.1080/00220388.2022.2032673

Anisimova, H.V., Donets, O.V. (2022). Mechanism of legal regulation of environmental risks for the preservation of biological diversity in conditions of sustainable development. Astra Salvensis, 1, 311–327.

Chen, T., Yang, F., Li, Y., Zhang, Z. (2024). Two-way FDI assists agricultural sustainable development: Based on digitization and greening perspectives. PLOS ONE, 19(2), e0296896. https://doi.org/10.1371/journal.pone.0296896

Dayıoğlu, M.A., Turker, U. (2021). Digital transformation for sustainable future – Agriculture 4.0: A review. Journal of Agricultural Sciences, 27(4), 373–399. https://doi.org/10.15832/ankutbd.986431

Diachynska, O. (2024). European integration priorities of agricultural land use. Economy and Society, 68. https://doi.org/10.32782/2524-0072/2024-68-59

Donets, O. (2019). Ecologization of the ownership right on the objects of fauna in the aquaculture area. In: O.V. Petryshyn (ed.). Yearbook of Ukrainian law, 11, 305–314. Kharkiv: Pravo.

Donets, O. (2021). Instituting principle for the reproduction (restoration) of natural resources and complexes in the context of ensuring and protecting fundamental human rights. Access to Justice in Eastern Europe, 4(12), 62–89. https://doi.org/10.33327/AJEE-18-4.4-a000085

Kryukova, I., Ihnatenko, M. (2025). Modernization of fixed assets of business entities in the agricultural sector under conditions of sustainable development. Herald of Khmelnytskyi National University. Economic Sciences, 340(2), 489–494. https://doi.org/10.31891/2307-5740-2025-340-77

MacPherson, J., Voglhuber-Slavinsky, A., Olbrisch, M., Schöbel, P., Dönitz, E., Mouratiadou, I., Helming, K. (2022). Future agricultural systems and the role of digitization for achieving sustainability goals: A review. Agronomy for Sustainable Development, 42(4), 70. https://doi.org/10.1007/s13593-022-00792-6

Mazur, V.V. (2025). Features of the use of digital technologies in the agricultural sector of Ukraine. Agrosvit, 9, 109–117. https://doi.org/10.32702/2306-6792.2025.9.109

Metelenko, N.H., Voronkova, V.H., Nikitenko, V.O., Ohloblina, V.O., Bielokon, K.V. (2025a). Synergy of digitization and environmental sustainability: Models for introducing green technologies into regional development. In: V. Shpak (ed.). Education and science: Theory and praxis, 50–68. Sherman Oaks, CA: GS Publishing Services.

Metelenko, N., Svintsova, N., Nikitenko, V. (2025b). Digitization of the agricultural sector as a tool for introducing green technologies in the context of sustainable development. Humanities Studies, 23(100), 256–266. https://doi.org/10.32782/hst-2025-23-100-29

OECD (2019). Digital opportunities for better agricultural policies. Paris: OECD Publishing.

OECD (2022). The digitalisation of agriculture: A literature review and emerging policy issues. Paris: OECD Publishing.

Ostapenko, I., Zadykhaylo, D., Lyseiuk, A., Tunitska, Y., Sierova, L. (2024). Global practices and experiences in developing a green economy amid financial crises. Grassroots Journal of Natural Resources, 7(3), 244–270. https://doi.org/10.33002/nr2581.6853.070314

Petrova, N.O. (2023). State and legal regulation of the agrarian sphere: Separate directions in the conditions of sustainable development and European integration. In: Modern paradigm of public and private law amidst sustainable development, 2, 139–171. Riga: Baltija Publishing.

Saúlko, D.P. (2024). Development of smart industry in the agricultural sector of the economy. http://socrates.vsau.org/repository/getfile.php/37762.pdf

Sharapova, S., Lisova, T., Bredikhina, V., Lialiuk, O. (2021). Improvement of land relations in the context of sustainable development of rural areas in Ukraine. Journal of Environmental Management and Tourism, 12, 7(55), 1899–1905. https://doi.org/10.14505/jemt.12.7(55).15

Sierov, I.V. (2024). Sustainable development of agribusiness through the introduction of eco-innovations. Ukrainian Journal of Applied Economics and Technology, 9(3), 407–411. https://doi.org/10.36887/2415-8453-2024-3-73

Tomashuk, I.V., Susidenko, Yu. V., Burdiak, M.I. (2024). Global trends in the development of the world economy in the context of digitization: Environmental aspect. Business Navigator, 2(75), 15–28. https://doi.org/10.32782/business-navigator.75-3

Tymoshenko, Y., Kyslenko, D., Kuzmichova-Kyslenko, E., Leonenko, I., Servetsky, I. (2022). Features of the pre-trial investigation of air pollution. Environment and Ecology Research, 10(2), 133–145. https://doi.org/10.13189/eer.2022.100203

UNEP, and FAO. (2020). Legislative Approaches to Sustainable Agriculture and Natural Resources Governance. https://www.unep.org/resources/publication/legislative-approaches-sustainable-agriculture-and-natural-resources

Zeng, F., Zhou, Y., Wei, B. (2024). Empowering sustainable development: Revolutionizing agricultural green total factor productivity through rural digitization. Frontiers in Sustainable Food Systems, 8, 1455732. https://doi.org/10.3389/fsufs.2024.1455732

INTEGRACJA REGULACJI PRAWNYCH W ZAKRESIE ZAZIELENIANIA ROLNICTWA ORAZ DIGITALIZACJI NA RZECZ ZRÓWNOWAŻONEGO ROZWOJU W EUROPIE

ABSTRAKT

Cel pracy

W świetle zobowiązań międzynarodowych i dążenia do zrównoważonego rozwoju niniejszy artykuł analizuje luki w przepisach krajowych, ocenia stopień zbieżności z unijnymi standardami środowiskowymi i cyfrowymi oraz formułuje zalecenia dotyczące harmonizacji ram regulacyjnych w celu wspierania zrównoważonego rozwoju.

Materiał i metody
Aby zbadać dostosowanie instytucjonalne, infrastrukturę technologiczną i praktyki zarządzania, zastosowano metodologię interdyscyplinarną, łączącą porównawczą analizę prawną, podejścia systemowe i historyczno-logiczne oraz studia przypadków kluczowych platform zarządzania cyfrowego w UE. W analizie wykorzystano przepisy UE, prawodawstwo ukraińskie, ramy analityczne OECD i UNEP-FAO, a także literaturę naukową.

Wyniki i wnioski
Wyniki wskazują na częściową zbieżność ukraińskiego systemu regulacyjnego z wymogami Unii Europejskiej. Do kluczowych obszarów problemowych zaliczyć należy: fragmentaryzację przepisów, ograniczoną interoperacyjność systemów danych rolniczych, słabą koordynację instytucjonalną oraz niewystarczające wsparcie dla małych i średnich gospodarstw rolnych. Analiza porównawcza wskazuje, że hybrydowy model UE, integrujący monitoring cyfrowy, warunkowość środowiskową i zarządzanie wielopoziomowe, dostarcza Ukrainie istotnych wniosków strukturalnych. Badanie identyfikuje priorytetowe obszary − odnoszące się do istniejących luk we wdrażaniu programów ekologicznych, w systemach doradczych, w zarządzaniu danymi, a także we współpracy międzysektorowej. Wzmocnienie potencjału instytucjonalnego, ustanowienie jednolitego monitoringu rolno-środowiskowego, zwiększenie interoperacyjności danych oraz rozszerzenie wsparcia dla MŚP będą niezbędne do skutecznego dostosowania do unijnej polityki rolnej i środowiskowej.

Słowa kluczowe: sektor rolny, Unia Europejska, zazielenianie, współpraca naukowo-techniczna, Ukraina