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Improving the system of indicators of digital transformation of the agricultural sector in the context of Ukraine's European integration

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ABSTRACT

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The article is devoted to improving the system of indicators of digital transformation of the agricultural sector in the context of Ukraine's European integration. Particular attention is paid to the implementation of digital innovations in the agricultural sector, increasing competitiveness and efficiency, and reducing the resource intensity of production. The purpose of the study is to substantiate the theoretical foundations and develop methodological approaches to improving the system of indicators of digital transformation of the agricultural sector of Ukraine, taking into account the requirements of European integration and adaptation to European standards for assessing digital development. In the course of the scientific study, general scientific methods of cognition were used, in particular: methods of theoretical generalization, analysis and synthesis, comparative analysis, statistical methods, expert and analytical method. Data collection covered the database of the State Statistics Service of Ukraine, the Global Innovation Index (WIPO), the European Commission (JRC, Eurostat), as well as the results of our own analytical processing of data from national and international reports on the digital economy and agriculture. The relationship between the indicators of the EU Common Agricultural Policy and the digital transformation of the agricultural sector of Ukraine has been established in accordance with the main areas of the CAP: sustainable development and "green" practices; innovation and knowledge; competitiveness and efficiency; social cohesion and development of rural areas; climate neutrality. The relationship between the indicators of the Global Innovation Index (GII) and the digitalization of the agricultural sector has been determined in accordance with the main groups of the GII: infrastructure (Infrastructure); human capital and research (Human capital & research); business development (Business sophistication); market development (Market sophistication); institutional environment (Institutions); knowledge and technological outputs (Knowledge & technology outputs); creative outputs (Creative outputs). A system of indicators of the digital transformation of the agricultural sector in the context of Ukraine's European integration (ADI EU) has been generalized and proposed in terms of target groups: infrastructure and access to technologies; digital skills and education; innovation and technology implementation; policy and institutional support; economic and environmental effect.

KEYWORDS

agricultural sector, digitalization, European integration, common agricultural policy, Global Innovation Index



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СОЦІАЛЬНИЙ РОЗВИТОК: економіко-правові проблеми

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Удосконалення системи індикаторів цифрової трансформації агросектору в умовах євроінтеграції України

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СТАТТЯ	АНОТАЦІЯ
Дослідницька DOI: 10.70651/3083-6018/2025.10.16 Авторське право © 2025 автора Цей твір ліцензовано на умовах Ліцензії Creative Commons «Із Зазначенням Авторства – Некомерційна 4.0 Міжнародна» (CC BY-NC 4.0).	Стаття присвячена удосконаленню системи індикаторів цифрової трансформації агросектору в умовах євроінтеграції України. Особлива увага приділяється впровадженню цифрових інновацій в агросекторі, підвищенню конкурентоспроможності і ефективності, зменшенню ресурсоемності виробництва. Мета дослідження полягає у обґрунтуванні теоретичних засад та розробленні методичних підходів до удосконалення системи індикаторів цифрової трансформації аграрного сектору України з урахуванням вимог євроінтеграції та адаптації до європейських стандартів оцінювання цифрового розвитку. У ході наукового дослідження використовувалися загальнонаукові методи пізнання, зокрема: методи теоретичного узагальнення, аналізу та синтезу, порівняльний аналіз, статистичні методи, експертно-аналітичний метод. Збір даних охоплював базу Державної служби статистики України, Global Innovation Index (WIPO), Європейської комісії (JRC, Eurostat), а також результати власного аналітичного опрацювання даних національних і міжнародних звітів щодо цифрової економіки та сільського господарства. Встановлено взаємозв'язок індикаторів Спільної аграрної політики ЄС та цифрової трансформації агросектору України відповідно до основних напрямів САП: сталий розвиток і «зелені» практики; інновації та знання; конкурентоспроможність і ефективність; соціальна згуртованість і розвиток сільських територій; кліматична нейтральність. Визначено взаємозв'язок показників Global Innovation Index (GII) та цифровізації агросектору відповідно до основних груп GII: інфраструктура (Infrastructure); людський капітал і дослідження (Human capital & research); розвиток бізнесу (Business sophistication); розвиток ринку (Market sophistication); інституційне середовище (Institutions); знання та технологічні результати (Knowledge & technology outputs); творчі результати (Creative outputs). Узагальнено та запропоновано систему індикаторів цифрової трансформації агросектору в умовах Євроінтеграції України (ADI EU) в розрізі цільових груп: інфраструктура та доступ до технологій; цифрові навички та освіта; інновації та впровадження технологій; політика та інституційна підтримка; економічний та екологічний ефект.

КЛЮЧОВІ СЛОВА

агросектор, цифровізація, євроінтеграція, спільна аграрна політика, Global Innovation Index

1. Introduction

The current stage of development of the agricultural sector of Ukraine is characterized by the active introduction of digital technologies, which is a key factor in increasing its competitiveness, efficiency and sustainability in the context of globalization [15]. In the context of European integration processes, Ukraine undertakes to adapt management, monitoring and reporting systems to the standards of the European Union, in particular in the field of digitalization of agriculture. This involves the creation of an effective system of indicators capable of comprehensively assessing the level, dynamics and results of the digital transformation of the agricultural sector.

At the same time, the current scorecard used in Ukraine remains fragmented, does not provide a complete reflection of digitalization processes, and is not consistent with European approaches to assessing the digital maturity of agricultural sectors (for example, with the Digital Economy and Society Index – DESI or EU Agricultural Digitalisation Index methodologies). The lack of a unified measurement methodology prevents the comparison of Ukrainian indicators with European ones, complicates the assessment of the effectiveness of state policy and reduces the investment attractiveness of the agricultural sector.

Improving the system of indicators of digital transformation will allow not only to create an objective analytical base for managerial decision-making, but also to integrate Ukrainian statistics into pan-European information and analytical platforms, to ensure monitoring of the implementation of the UN Sustainable Development Goals and the policy of the EU Green Deal [5; 6]. This will increase the efficiency of agricultural production, develop human capital, expand the digital services market, and foster an innovative agricultural ecosystem in Ukraine.

Thus, the study aimed at improving the system of indicators of digital transformation of the agricultural sector in the context of European integration is timely and of great scientific and practical importance for the formation of an effective state policy for digital development, harmonization of national statistical approaches with European standards and ensuring sustainable development of the agricultural sector.

2. Literature Review

The issue of improving the system of indicators of digital transformation of the agricultural sector in the context of Ukraine's European integration is insufficiently researched in the domestic literature, since the direction is relatively new. Digital transformation acts not only as a technical stage of modernization, but also as a profound institutional change that transforms the principles of functioning of agricultural enterprises, increasing their flexibility, openness and ability to quickly adapt to new conditions [20]. Comprehensive digitalization means a large-scale transition of agro-economic systems to the use of digital technologies in all areas of activity, as well as their deep integration into digital ecosystems based on unified digital platforms and standards of interaction [18]. Building a digital economy in Ukraine requires the formation of a long-term strategy and a holistic state policy in the field of digitalization, which should be based on taking into account the European digital course and based on the experience of the EU. The state policy of digital development of Ukraine should cover the main directions defined in the digital policy of the European Union [11]. According to the research of many scientists, institutions and the institutional environment play an important role in the issue of innovation support, including European integration processes, in Ukraine [2; 16; 22]. An important role in this is played by the objects that will act as indicators, as well as the methods of their generalization and display [14; 24; 28].

Several foreign authors who have studied indicators of sustainable development in other sectors [3; 14], i.e., regional analysis is also possible in the agricultural sector regarding indicators of sustainability and agricultural policy [26]. Other authors focus on sustainable development indicators and their impact on European agricultural policy [8; 17]. A significant part of the authors investigates the impact of innovation and digitalization on sustainable development and agricultural policy, including the development of farming [9; 10–13; 27].

Despite the presence of a significant number of scientific papers on strategies and mechanisms of digital transformation of the agricultural sector, there is still a lack of generalized studies that take into account regional specifics and the context of European integration. Therefore, information materials

from various sources were analyzed, summarized and systematized in accordance with the subject of this study.

3. Problem Statement

The purpose of the study is to substantiate the theoretical foundations and develop methodological approaches to improving the system of indicators of digital transformation of the agricultural sector of Ukraine, taking into account the requirements of European integration and adaptation to European standards for assessing digital development. To achieve this goal, the following tasks will be performed: to explore European approaches to digitalization monitoring; to develop a structure and a list of improved indicators of digital transformation of the agricultural sector, harmonized with European requirements.

4. Methods and Materials

The methodological basis of the study is systemic, process and institutional approaches to the analysis of the digital transformation of the agricultural sector of the economy. To achieve this goal, a complex of general scientific and special research methods was used: methods of theoretical generalization, analysis and synthesis, comparative analysis, statistical methods, and expert-analytical method. The empirical basis of the study is made up of statistical materials of the State Statistics Service of Ukraine, Global Innovation Index (WIPO), the European Commission (JRC, Eurostat), as well as the results of its own analytical processing of data from national and international reports on the digital economy and agriculture.

5. Results and Discussion

The digitalization of agriculture and rural areas in the EU supports the modernization, competitiveness and sustainable development of agriculture. It promotes the integration of digital technologies and data-driven approaches, while improving the well-being of rural communities. The Common Agricultural Policy (CAP) is an EU strategic policy aimed at supporting farmers, rural development, food security and environmental sustainability.

The main goals of the Common Agrarian Policy are [25]:

1. Ensuring a fair income for farmers;
2. Increasing the competitiveness of agriculture;
3. Strengthening the position of farmers in the supply chain;
4. Protection of the environment, biodiversity and climate;
5. Support for sustainable rural development;
6. Attracting innovation, digitalization and knowledge.

Digital technologies can act as tools to facilitate the achievement of all specific objectives of the Common Agricultural Policy (CAP), in particular economic, environmental, climate and rural objectives.

By creating a conducive environment, the European Union is working on human-centered digitalization. This will reduce the digital divide between urban and rural areas and allow farmers and rural communities to adopt and use digital technologies effectively. The key objective of SAP 2023-27 is to modernize agriculture and rural areas by promoting and sharing knowledge, innovation and digitalization.

The SAP promotes an integrated approach to the digitalization of agriculture and rural areas, not only at the farm level, but also for the modernization of administration. EU countries have developed digitalization strategies for the first time as part of their SAP Strategic Plans, contributing to the promotion of digitalization in agriculture and rural areas. These strategies are adapted to the unique situation of each country [23]. They explore the potential of digital technologies to align with SAP-specific and cross-sectoral goals, and identify requirements to promote the adoption and sustainable use of digital technologies.

EU countries are also working to find mutual benefits with other policy instruments and actions, ensuring a holistic approach to digitalization. Building on the portfolio of SAP activities at their disposal, EU countries are strategically promoting digitalization, focusing on critical areas such as infrastructure,

training, skills development and the implementation of advanced technologies, including precision farming. To monitor the effectiveness of the Common Agricultural Policy (CAP), the Common Monitoring and Evaluation Framework (CMEF) system is used (Table 1).

Table 1. Relationship between the indicators of the EU Common Agricultural Policy and the digital transformation of the agricultural sector of Ukraine

CAP direction	How digitalization manifests itself	Key digital indicators
Sustainable development and green practices	Use of precision farming systems, monitoring of fertilizers and pesticides using sensors and satellites	Proportion of farms using digital technologies to monitor soil/yield
Innovation and knowledge	Support for projects within the framework of EIP-AGRI (European Partnership for Innovation), digital hubs	Number of projects with digital solutions that received CAP funding
Competitiveness and efficiency	Use of big data, IoT, and automated resource accounting systems	Labor productivity in digitally active farms vs traditional ones
Social cohesion and rural development	Online platforms for rural businesses, digital advisory services	Share of farmers with access to high-speed Internet
Climate neutrality	Use of satellite monitoring (Copernicus), GIS systems for land management	Digital Monitoring Level in Emission Assessment Systems

Source: Systematized by the authors according to the data given in [21; 25].

One of the important systems of indicators of the EU Common Agricultural Policy is the Global Innovation Index (GII). GII and the level of digitalization of the agricultural sector do have interrelated indicators that can be used for benchmarking or building correlation models. GII is often an integral indicator of innovation potential, while the level of digitalization of the agricultural sector is one of the effective indicators of its implementation (Table 2).

Table 2. Global Innovation Index (GII) and digitalization of the agricultural sector: interconnection of indicators

GII indicator group	Examples of GII indicators	Similar or tangential indicators of digitalization in the agricultural sector	Scope of interconnection
Infrastructure	- ICT access - ICT use - E-government (E-gov) - Energy infrastructure	- Level of digital coverage of rural areas (4G/5G) - Share of households with Internet - Use of GPS, IoT, and drones	Technological base of digitalization: digital solutions in agriculture are not possible without infrastructure
Human capital and research (Human capital & research)	- Quality of education - Number of scientists (R&D personnel) - Education costs (%)	- Digital literacy of farmers - AgriTech training programs - Number of specialists in the field of smart farming	Preparing Human Capital for the Use of Digital Technologies in Agriculture
Business sophistication	- Companies' investments in R&D - Cooperation between business and science - Number of knowledge-intensive employees	- Joint projects of agricultural companies and IT startups - R&D centers of agricultural technologies - Venture investments in AgriTech	An innovation ecosystem that drives digital solutions in the agricultural sector
Market development (Market sophistication)	- Access to loans and venture capital - Development of the financial market	- Investing in digital farms - Financing of agricultural innovations and startups	Access to finance is the key to introducing new digital technologies
Institutional environment (Institutions)	- Government efficiency - Quality of the regulatory environment - Protection of property rights	- Availability of state programs for the digitalization of agriculture - Legislative framework for the use of data (data governance)	State support for digitalization in the agricultural sector
Knowledge & technology outputs	- Number of patents - High-tech exports - Scientific publications	- Patents for agricultural technologies - Developments in the field of precision agriculture - Number of AgriTech startups	Effectiveness of digital innovations in the agricultural sector
Creative outputs	- ICT and creative industries	- Use of digital platforms for agrimarketing	Innovative application of digitalization for market differentiation

GII indicator group	Examples of GII indicators	Similar or tangential indicators of digitalization in the agricultural sector	Scope of interconnection
	- The impact of innovation in business	- Smart products, traceability systems	

Source: Systematized by the authors according to the data given in [4].

Objectives of the system of indicators of digital transformation of the agricultural sector in the context of Ukraine's European integration (what should be measured):

1. The level of penetration of digital technologies in agriculture (infrastructure + equipment);
2. Data availability and data quality/data exchange (interoperability, platforms);
3. The level of use of digital solutions (Precision Farming, drones, IoT, ERP, electronic services);
4. Human capital – digital skills of agricultural producers and consultants;
5. Economic impact – productivity, costs, profitability, labor market;
6. Environmental and sustainable effect (saving water/fertilizers, reducing emissions);
7. Regulatory/policy compliance – implementation of EU requirements (CAP, digital standards);
8. Risks – cybersecurity, data privacy, digital stratification between regions.

Based on the above data, it is proposed to improve the system of indicators of digital transformation of the agricultural sector in the context of European integration of Ukraine (ADI EU) (Table 3).

Table 3. System of Indicators of Digital Transformation of the Agricultural Sector in the Context of European Integration of Ukraine (ADI EU)

Indicator	SubIndicator
1. Infrastructure and access to technology	1.1 Internet access in rural areas
	1.2 Mobile and 4G/5G coverage
	1.3 Accessibility of digital devices
2. Digital skills and education	2.1 Farmers' Digital Literacy Rate
	2.2 Availability of educational programs in agricultural technologies
	2.3 Institutions that support AgriTech training
3. Innovation and technology adoption	3.1. Use of "smart" farming
	3.2 Applications of Artificial Intelligence, Big Data, Satellite Monitoring
	3.3 Startups and innovative solutions in the field of agriculture
4. Policy and institutional support	4.1 State programs for the digitalization of the agricultural sector
	4.2 support for startups, R&D, agrotech clusters
	4.3 National strategies for the development of digital agriculture
5. Economic and environmental effects	5.1 Performance Enhancement
	5.2 Cost reduction
	5.3 Sustainability of production (efficient use of resources, reduction of emissions)

Source: Systematized by the authors according to the data given in [4; 19; 21; 25].

6. Conclusions

Thus, the EU Common Agricultural Policy contains indicators that can be used to determine the degree of compliance of countries with generally accepted strategies, including in the agricultural sector. The digitalization of all sectors of the economy necessitates the allocation of new indicators. This also applies to agriculture and rural areas. In general, digitalization indicators without taking into account the industry direction are partially components of the Global Innovation Index (GII) indicators.

The indicators of digital transformation of the agricultural sector can be considered a sectoral sub-index that focuses on digital innovations in agriculture. Taking into account the European integration direction of the development of the Ukrainian economy, including in agriculture, the System of Indicators of Digital Transformation of the Agricultural Sector in the Context of European Integration of Ukraine (ADI EU) has been proposed. This system will allow for a better assessment of the state of digital European integration of the agricultural sector of Ukraine.

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