THE IMPACT OF DIGITAL INNOVATIONS ON THE DEVELOPMENT OF AGRICULTURAL BUSINESS

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Abstract. The **purpose** of this article is to study the impact of digitalization on the innovative development of agricultural enterprises, identify key technologies that increase efficiency and competitiveness, analyze the global experience of implementing digital solutions, and develop practical recommendations for using digital technologies as a driver of innovative growth in the agricultural sector of Ukraine. *Methodology.* In order to achieve the research objective and accomplish the defined tasks, a comprehensive approach has been employed, incorporating the following methods: analysis, synthesis, systematisation and classification, induction and deduction, and others. The findings of the study suggest that the integration of digital technologies has the potential to optimise production processes, enhance labour productivity, and reduce costs. Specifically, technologies such as precision farming, drone usage for field monitoring, automated irrigation systems, and robotic harvesting have been shown to significantly enhance operational efficiency. The analysis indicates that the adoption of digital solutions enables agricultural enterprises to achieve cost reductions of 10-20%, increase crop yields by 15-25% through enhanced resource management, and reduce post-harvest storage losses by 5-10%. The primary obstacles hindering the integration of digital innovations encompass the substantial expense associated with adopting sophisticated technologies, inadequate digital literacy among personnel, the absence of adequate infrastructure in rural regions, and constrained access to financial resources. The study's results are presented in the form of tables, figures, graphs, diagrams, and charts. *Practical implications.* The implementation of digital technologies enables agricultural enterprise managers to obtain precise, real-time data on production conditions. Consequently, this facilitates informed decision-making processes, leads to a reduction in production costs, and optimises resource utilisation. *Value/Originality.* Digitalisation has been demonstrated to enhance the resilience of enterprises to market challenges, thereby facilitating improvements in productivity and revenue generation. The digitalisation of the agricultural sector has the potential to generate new investment and grant opportunities. The present study contributes to the development of digital literacy and the enhancement of professional qualifications among workers in the agricultural sector. The use of digital innovations improves the stability and efficiency of production, which is crucial for ensuring the supply of quality products to the population. Digitalisation also creates new employment opportunities in rural areas, helping to reduce labour migration. Digital solutions also help to minimise environmental damage. Digitalisation of the agricultural sector is a key component of Ukraine's sustainable economic development strategy.

Keywords: digitalisation, agricultural enterprises, innovative development, digital technologies, innovations, competitiveness, management, digital economy, agro-industrial sector.

JEL Classification: O13, O31, O33, O57, Q19

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1. Introduction

In today's world, digitalisation is becoming the main driver of development in many sectors of the economy, especially in agriculture. Innovative technologies such as the Internet of Things (IoT), big data, drones, automation of production processes, blockchain and other digital solutions offer new opportunities to increase efficiency, reduce costs and ensure the sustainable development of agricultural enterprises. It is imperative to acknowledge the pivotal role of the agricultural sector in both the Ukrainian economy and the global economy. The implementation of digital technologies is paramount for enhancing competitiveness and promoting innovative growth.

In the context of globalised markets and the escalating demand for agricultural products, agricultural enterprises are compelled to expeditiously adapt to prevailing changes and adopt innovative management methodologies. Digitalisation is becoming an essential tool for not only reducing costs but also for creating new business models and opportunities within the agribusiness sector. As the digitalisation of the agricultural sector in Ukraine continues to gain momentum, many enterprises still face several challenges, such as incomplete infrastructure, limited funding, and a lack of qualified personnel. Consequently, research into digitalisation as a driver of innovative development is highly relevant. The identification of optimal strategies for the implementation of digital technologies, the overcoming of barriers to their adoption, and the provision of recommendations for enterprises of various sizes to improve efficiency and competitiveness are all objectives that can be facilitated by such research.

Consequently, investigating this subject is a pivotal step in formulating a sustainable, innovative, and efficient agricultural sector with the capacity to compete in international markets and guarantee food security. The present article aims to achieve several objectives. Firstly, it will examine the impact of digitalisation on the innovative development of agricultural enterprises. Secondly, it will identify key technologies that enhance efficiency and competitiveness. Thirdly, it will analyse global experiences in implementing digital solutions. Finally, it will develop practical recommendations for using digital technologies as a driver of innovative growth in Ukraine's agricultural sector.

In order to achieve this objective, the following tasks were defined To explore existing digital tools and innovative practices implemented in agricultural enterprises; to identify key trends in the digitalisation of agriculture at both national and global levels; to examine the relationship between the level of digitalisation of enterprises and their competitiveness; to identify external and internal factors that limit the implementation of digital technologies in agriculture; to propose tools, strategies and models for the effective implementation of digital technologies in the activities of agricultural enterprises; to formulate recommendations for improving digital literacy of staff and access to finance; and to explore the impact of digitalisation on the environmental sustainability, economic development and social aspects of agriculture.

The following research methods were applied: analysis (to review scientific literature, international reports, regulatory documents, and practical case studies on digitalisation in the agricultural sector); synthesis (to identify the key concepts of digitalisation as a driver of innovative development); systematisation and classification (to categorise digital technologies influencing the development of agricultural enterprises and systematise the main challenges and benefits of digitalisation for enterprises of various scales); induction and deduction (to determine the relationships between the implementation of digital technologies and the growth of innovation in agricultural enterprises, and to generalise the results obtained and formulate recommendations); comparative analysis (to examine global experiences in the digitalisation of agricultural enterprises in leading countries, aiming to identify best practices and compare the state of digitalisation in Ukraine's agricultural sector with that in other countries); statistical analysis (to utilise statistical data to assess the impact of digital technologies on the productivity, efficiency, and profitability of agricultural enterprises, and to evaluate the dynamics of digital technology development in agriculture); forecasting (to create forecasts on the future impact of digitalisation on the innovative development of Ukraine's agricultural sector); modelling (to develop a model for assessing the economic benefits of introducing digital technologies into the operations of agricultural enterprises); development of recommendations (to formulate practical recommendations for enterprises, including steps for the implementation of digital technologies, improving staff qualifications, and creating a favourable environment for innovation); and barrier assessment (to analyse the barriers to digitalisation in Ukraine (financial, organisational, infrastructural) and propose ways to overcome them).

This study examines the key aspects of digitalisation, which is a crucial factor in the innovative development of the agricultural sector. Digitalisation enables the sector to adapt to modern challenges and create new opportunities for sustainable growth. The paper explores contemporary digital technologies, including precision farming, process automation, the Internet of Things (IoT), and blockchain, which contribute to improving production efficiency, optimising costs, and enhancing product

quality. Key challenges are identified, including low digital literacy, limited financial resources and infrastructure constraints. Practical recommendations are proposed to overcome the barriers to digitalisation and ensure the sustainable development of the agricultural sector.

2. Digital Technologies in the Agricultural Sector

In response to global trends, the growing demand for food, climate change, and resource constraints, digitalisation is becoming a key factor in the transformation of the agricultural sector.

According to United Nations forecasts, the global population is expected to reach 10 billion by 2050, requiring a 70% increase in food production. This necessitates the optimisation of production processes, in which digital technologies play a pivotal role. The unpredictability of climatic conditions, marked by phenomena such as droughts, floods, and other extreme events, has been demonstrated to exert a substantial influence on crop yields. Digital solutions, such as weather forecasting and soil and crop monitoring, empower farmers to adapt to these conditions and mitigate negative consequences.

Agriculture is experiencing a growing shortage of water, land, and energy resources (Palamarchuk, Honcharuk, Honcharuk, Telekalo, 2018). Digital

technologies, particularly precision farming, facilitate the efficient utilisation of resources, thereby reducing costs and minimising environmental impact (Sydoruk, Sava, Korzhenivska, Zdyrko, Khaietska, 2021). The agricultural sector is a major industry in many countries, including Ukraine. In order to maintain competitiveness, enterprises are compelled to adopt innovative technologies that ensure superior product quality, augmented production efficiency, and enhanced transparency within supply chains (Yaroschuk, 2024).

The advent of novel solutions, including big data, the Internet of Things (IoT), blockchain technology, drones, artificial intelligence, and robotics, facilitates the automation and enhancement of all phases of production, from soil preparation to product shipment.

Digital technologies help to reduce the carbon footprint of the agricultural sector by reducing the use of chemicals, optimising energy consumption and minimising waste (Palamarchuk, Honcharuk, Honcharuk, Telekalo, 2018). Table 1 shows the main areas of application of digital technologies in the agricultural sector.

Digital technologies in the agricultural sector engender novel opportunities for the optimisation of production, the augmentation of yields, and the more efficient utilisation of resources.

Table 1

Key areas of application of digital technologies in the agricultural sector

No.	Digital technology name	Application areas	Essential characteristics of their use
1	*Agricultural drones*	Field monitoring	• The drones are equipped with cameras and sensors that allow us to assess the condition of crops, detect diseases or pests.
2		Precise application of fertilisers and pesticides	• Thanks to GPS navigation, drones provide localized application of substances, reducing costs.
3	*Internet of Things (IoT)*	Smart sensors	• They measure soil moisture, temperature, and solar radiation, which allows for efficient irrigation management and planning of agricultural activities.
4		Automated irrigation systems	• Operates based on sensor data, ensuring water savings.
5	*Satellite and Geographic Information Systems (GIS)*	Field mapping	• Satellites provide data to create accurate maps that help optimise the use of fertilisers and resources.
6		Weather monitoring	• Forecasting climate change for crop planning.
7	*Robotics*	Autonomous tractors	• Used for plowing, sowing, harvesting without human intervention.
8		Mobile robots	• They can be used for weeding, harvesting or even monitoring the condition of plants.
9	*Artificial Intelligence (AI) and Data Analytics*	Yield forecasting	• Analysis of large data sets to identify the most productive areas of the field.
10		Disease detection	• AI analyses images of plants and identifies potential problems before humans can.
11	*Digital platforms and mobile applications*	Farm management	• Applications enable users to keep records, schedule transactions, and track expenses.
12		E-commerce	• Platforms for selling agricultural products directly to consumers or partners.
13	*Blockchain technologies*	Supply chain transparency	• Tracking products from field to table, ensuring consumer trust.
14		Contracts between farmers and suppliers	• Smart contracts simplify financial transactions.

Source: (Rudenko, 2019; Yarmoliuk, Abramov, Mulyk, Smirnova, Ponomarova, 2024)

3. The Advantages and Challenges of Digitalisation for Agricultural Enterprises

The digitalisation of the agricultural sector has been shown to have a significant impact on the efficiency and competitiveness of enterprises (Koliadenko, Andreichenko, Galperina, Minenko, Kovylina, 2020). Nevertheless, in addition to the advantages it engenders, it concomitantly poses certain challenges.

Digitalisation has emerged as a pivotal element in the evolution of contemporary agricultural enterprises. While its implementation offers significant benefits, a comprehensive approach is required, including financing, staff training, infrastructure improvements, and addressing legal issues. Achieving a balance between the advantages and challenges presented by digitalisation is imperative for ensuring the sustainable development of the agricultural sector (see Table 2).

The efficacy of digital technologies in the agricultural sector is evident, as they significantly increase productivity, reduce costs, improve product quality, and promote sustainable development. Digitalisation also helps to reduce environmental impact, enhance risk management, and create new opportunities for entering international markets (Tomashuk, Susidenk, Burdyak, 2024). Table 3 presents a SWOT analysis of the impact of digital innovations on the development of agricultural business.

This SWOT analysis will facilitate the identification of strategic directions for the development and optimisation of digital innovation implementation in the agricultural sector. The utilisation of digital technologies has become an indispensable instrument for ensuring the competitiveness of agricultural enterprises in the global market.

4. Global Experience of Digitalisation in the Agricultural Sector

The implementation of digital technologies within the agricultural sectors of developed countries has

Table 2

Benefits and challenges of digitalisation for agricultural enterprises

Benefits of digitalisation for agricultural enterprises	Challenges of digitalisation for agricultural enterprises
Increased efficiency • The use of digital solutions reduces the consumption of resources (water, fertiliser, fuel) through precise process control. •Automation of routine tasks, such as yield accounting or logistics management.	*High implementation cost* • Purchasing equipment, developing software, connecting to IoT require significant financial investments. • Larger enterprises have more resources, while small farmers often face financial barriers.
Optimisation of production processes • Precision farming technologies allow to determine the optimal areas for sowing and fertilising. • Rapid response to changing conditions (weather, soil condition, spread of diseases).	*Insufficient level of digital literacy* • Employees often lack the knowledge and skills to work with new technologies. • The need to train staff requires additional time and resources.
Improving product quality • Precise control over growing conditions ensures stable quality of agricultural products. • Transparency of the production process through blockchain increases consumer trust.	*Infrastructure issues* • Lack of access to high-speed internet in rural areas. • Low level of smart infrastructure development in agricultural regions.
Environmental sustainability • Smart irrigation and monitoring systems help reduce environmental impact. • Reduced CO_2 emissions through optimised transportation and resource use.	*Cybersecurity* • The use of digital solutions makes businesses vulnerable to hacker attacks, data loss, or theft of commercial information. • Blockchain and other secure technologies can be expensive.
Access to new markets • Electronic platforms for selling products allow for international expansion. • Simplification of co-operation with processing plants and retail chains.	*Integration difficulty* • Not all digital systems integrate easily with existing processes and equipment. • Problems with data standardisation and cross-platform compatibility.
Forecasting and analytics • Big data analysis helps predict yields and optimise planting and harvesting times. • Forecasting risks such as drought, plant diseases or market fluctuations.	*Legal and ethical issues* • Issues of collecting and storing user data, which are regulated by law. • The need to comply with environmental and social standards. Skepticism and resistance to change • Farmers often perceive digitalisation as an additional challenge or do not believe in its effectiveness. • Traditional approaches remain popular, especially among older generations.

Source: (Rudenko, 2019; Samoilenko, 2024; Soloviova, Krasnyak, Cherkaska, Revkova, 2022)

Table 3
SWOT analysis of the impact of digital innovations on the development of agricultural business

S (Strengths):	W (Weaknesses):
• *Increased efficiency.* Reducing costs through process automation. • *Precision farming.* Using data to optimize yields and resources. • *Improved management.* Digital platforms simplify monitoring and planning. • *Access to markets.* Online trading expands product distribution opportunities.	• *High cost of implementation.* Investment in technology may be out of reach for small businesses. • *Insufficient digital literacy.* Lack of skills among agricultural workers. • *Infrastructure dependency.* Need for stable internet and power supply. • *Cyber risk.* Vulnerability to data leaks and technical failures.
O (Opportunities):	T (Threats):
• *Government support.* Digitalisation funding programs. • *New markets.* Using e-commerce platforms. • *Development of agro-tech startups.* Partnerships with innovative companies. • *Global trends.* Increasing demand for "smart" agriculture.	• *Economic instability.* Financing constraints due to external factors. • *Climate risks.* Technologies may not be effective enough to adapt to extreme conditions. • *Competition.* Large market players may gain an advantage due to better access to resources. • *Rapid pace of change.* The constant need to update technologies and meet modern requirements.

Source: (Yurchuk, Kiporenko, 2022; Yarmoliuk, Abramov, Mulyk, Smirnova, Ponomarova, 2024).

become a pivotal factor in enhancing efficiency, product quality, and sustainable development. It is imperative for other countries, notably Ukraine, which possesses considerable agricultural potential but faces numerous challenges in the process of digitalisation, to study and apply this experience.

The global experience of digitalising the agricultural sector demonstrates a variety of approaches to the implementation of modern technologies. Examples and practices of digitalisation in the agricultural sectors of different countries are presented in Figure 1.

Today, digitalisation offers unique opportunities for transformation. Critical sectors and industries essential to development, such as healthcare, education, energy and agriculture, depend on connectivity and databases.

In low-income countries, billions of people still lack access to the Internet, digital identification tools, or digital skills. To bridge the digital divide, the World Bank is working with the governments of more than 100 developing countries to build a strong and reliable foundation for the growth of the digital economy. The digital lending portfolio has reached a record 53 active projects, with a total net volume of 5.6 billion USD in reserved funds as of June 2024. A decision was taken to allocate over a third of the funds (37%) in the 2024 financial year. Furthermore, demand from middle-income countries has increased from 5% in the 2021 financial year to 24% in the 2024 financial year, reflecting the growing recognition of the crucial role digital technologies play in enhancing climate resilience, driving economic growth, creating jobs, and improving the delivery of public services (https://www.worldbank.org).

A global perspective on the implementation of digital technologies in the agricultural sector reveals that such technologies are instrumental in enhancing productivity, efficiency, and sustainable development. Table 4 presents a comparative analysis of the future of the networked economy and provides a ranking of countries for 2024.
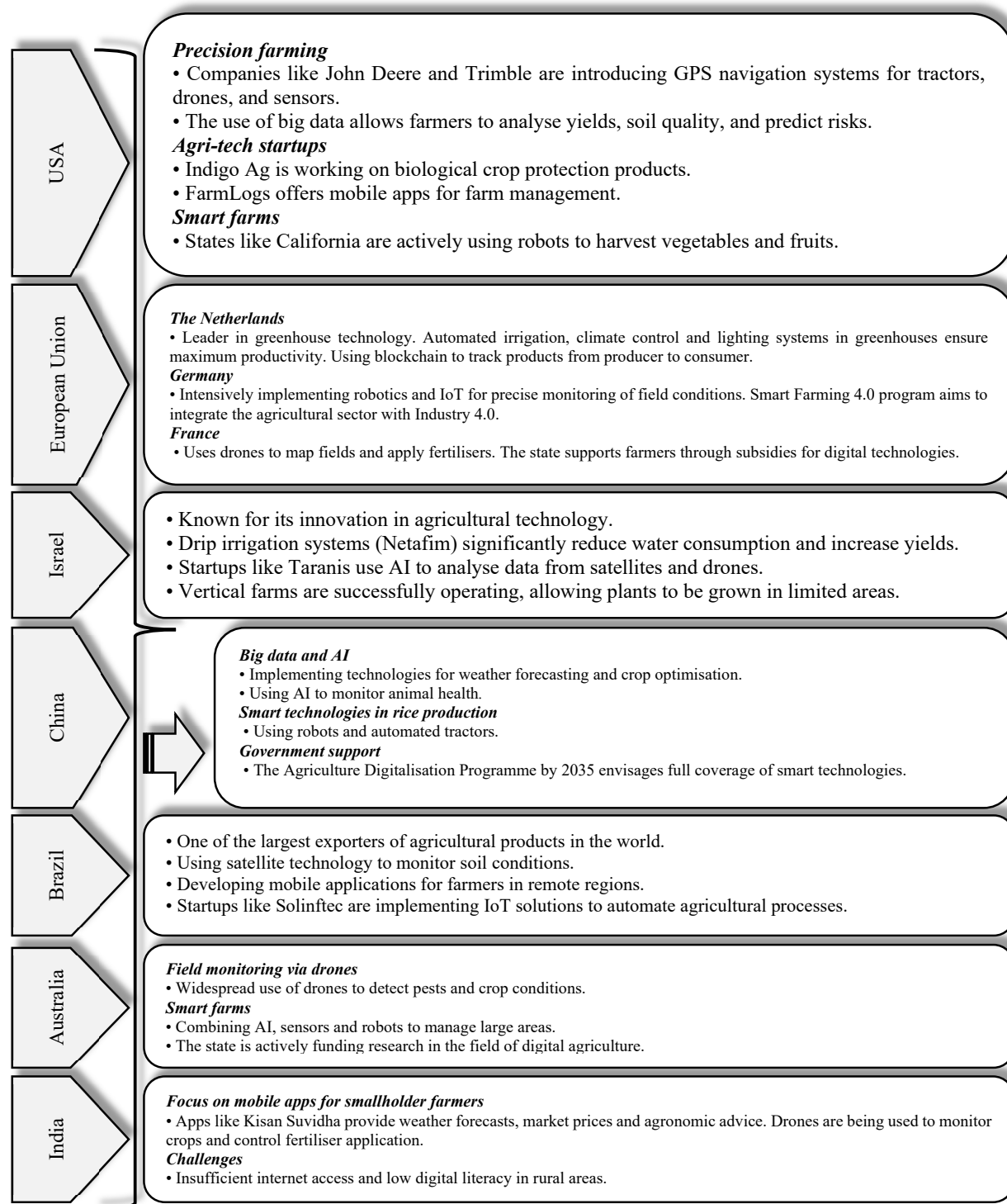
In consideration of its considerable agricultural potential, Ukraine is presented with the opportunity to adopt best practices for the development of its agricultural sector, thus overcoming the challenges it faces and enhancing its competitiveness in global markets. A critical step in this process will be to study international experiences and adapt them to local conditions, thereby facilitating the innovative development of agriculture.

5. Digitalisation of Agricultural Enterprises in Ukraine

In the context of mounting global challenges, climate change, intensified competition in international markets, and a growing demand for products, the digitalisation of Ukraine's agricultural sector is acquiring increasing importance (Soloviova, Krasnyak, Cherkaska, Revkova, 2022). However, this process is characterised by specific features that are related to the development characteristics of the country's agricultural sector, the availability of technologies, and the level of state support.

Ukraine is a major global player in the export of grain and oilseeds, a position that gives rise to a significant demand for innovative technologies to enhance productivity. The presence of several climatic zones allows for the cultivation of a wide range of crops, which requires the implementation of tailored digital solutions.

Some large companies have already adopted GPS navigation technologies, drones to monitor crop conditions, sensors to assess soil quality and weather

USA

Precision farming
• Companies like John Deere and Trimble are introducing GPS navigation systems for tractors, drones, and sensors.
• The use of big data allows farmers to analyse yields, soil quality, and predict risks.
Agri-tech startups
• Indigo Ag is working on biological crop protection products.
• FarmLogs offers mobile apps for farm management.
Smart farms
• States like California are actively using robots to harvest vegetables and fruits.

European Union

The Netherlands
• Leader in greenhouse technology. Automated irrigation, climate control and lighting systems in greenhouses ensure maximum productivity. Using blockchain to track products from producer to consumer.
Germany
• Intensively implementing robotics and IoT for precise monitoring of field conditions. Smart Farming 4.0 program aims to integrate the agricultural sector with Industry 4.0.
France
• Uses drones to map fields and apply fertilisers. The state supports farmers through subsidies for digital technologies.

Israel

• Known for its innovation in agricultural technology.
• Drip irrigation systems (Netafim) significantly reduce water consumption and increase yields.
• Startups like Taranis use AI to analyse data from satellites and drones.
• Vertical farms are successfully operating, allowing plants to be grown in limited areas.

China

Big data and AI
• Implementing technologies for weather forecasting and crop optimisation.
• Using AI to monitor animal health.
Smart technologies in rice production
• Using robots and automated tractors.
Government support
• The Agriculture Digitalisation Programme by 2035 envisages full coverage of smart technologies.

Brazil

• One of the largest exporters of agricultural products in the world.
• Using satellite technology to monitor soil conditions.
• Developing mobile applications for farmers in remote regions.
• Startups like Solinftec are implementing IoT solutions to automate agricultural processes.

Australia

Field monitoring via drones
• Widespread use of drones to detect pests and crop conditions.
Smart farms
• Combining AI, sensors and robots to manage large areas.
• The state is actively funding research in the field of digital agriculture.

India

Focus on mobile apps for smallholder farmers
• Apps like Kisan Suvidha provide weather forecasts, market prices and agronomic advice. Drones are being used to monitor crops and control fertiliser application.
Challenges
• Insufficient internet access and low digital literacy in rural areas.

Figure 1. International experience of digital transformation of the agricultural sector

Source: (Samoilenko, 2024; Chikov, Radko, Marshalok, Tepliuk, Petrenko, Sharko, Sitkovska, 2022)

stations. Agricultural management platforms are emerging to help optimise costs, plan yields and manage logistics. The use of blockchain technology ensures transparency in supply chains, which is particularly important for exporting Ukrainian products to international markets. While large farms have access to modern technology, small and medium-sized farms often face financial challenges.

In rural areas, access to high-speed internet is a major issue, which is crucial for the implementation of digital solutions. Although there are government programmes for agricultural development, digitisation

Table 4
Benchmarking the Future of the Network Economy: Ranking Countries, 2024

ISO3	Country	Score	Rank	Technology
USA	United States of America	78.96	1	82.24
SGP	Singapore	76.94	2	71.20
FIN	Finland	75.76	3	66.63
SWE	Sweden	74.99	4	69.28
KOR	Republic of Korea	74.85	5	66.78
NLD	Netherlands	73.94	6	73.71
CHE	Switzerland	73.71	7	74.85
GBR	United Kingdom	73.57	8	71.38
DEU	Germany	73.54	9	72.54
DNK	Denmark	72.70	10	67.70
CAN	Canada	71.76	11	67.23
JPN	Japan	70.96	12	63.78
ISR	Israel	70.46	13	55.18
NOR	Norway	69.70	14	63.47
AUS	Australia	69.43	15	60.54
FRA	France	68.71	16	64.90
CHN	China	68.70	17	65.34
EST	Estonia	67.85	18	53.56
IRL	Ireland	66.20	19	54.54
AUT	Austria	66.05	20	59.93
UKR	Ukraine	55.32	43	48.96

Source: (https://networkreadinessindex.org/countries/)

is not yet a priority. There is a lack of financial instruments (such as grants and concessionary loans) to support the adoption of digital technologies. In addition, legislation regulating the circulation and use of data in the agricultural sector needs to be improved. Figure 2 shows data on the Digital Transformation Index of Hromadas in Ukraine as of July 2023.

In July 2024, the European Union identified future digital innovation hubs in Ukraine, which will join the European network under the EU programme "Digital Europe". European Digital Innovation Hubs (EDIHs) are defined as centres that provide support to small and medium-sized enterprises and public organisations in the enhancement of production processes, products, or services through the utilisation of digital technologies (Innovation hubs in Ukraine, EU "Digital Europe").

The Ukrainian agricultural sector has incurred direct losses and damages exceeding 80 billion USD due to the full-scale Russian invasion. The estimated value of destroyed assets is 10.3 billion USD, representing an 18% increase on the estimate made in April 2023. The most significant category of losses pertains to agricultural machinery, accounting for 5.8 billion USD, which constitutes 56.7% of the total losses. It is estimated that approximately 181,000 units of agricultural machinery and equipment have been partially or completely damaged. The estimated financial impact of theft or destruction of existing

products is 1.97 billion USD, whereas losses incurred from damaged grain storage facilities are estimated at 1.8 billion USD. The total estimated losses incurred by perennial crops are 398 million USD, livestock losses amount to 254 million USD, and losses in aquaculture and fishing are estimated at 35 million USD. Concurrently, losses, encompassing unrealised income of agricultural producers and elevated production costs, have more than doubled in comparison with the preceding review, reaching 69.8 billion USD. The total losses incurred due to diminished crop production are estimated at 35.1 billion USD, whereas the losses arising from the contraction in livestock production are calculated to be 5.6 billion USD. It is estimated that losses resulting from the decline in domestic prices amount to 24.1 billion USD. Additionally, losses incurred due to elevated production costs are estimated at 4.4 billion USD (Tarasovsky, 2024).

At present, a paucity of specialists in digital technologies is being experienced within Ukraine's agricultural sector, a state of affairs which limits their widespread implementation. While there has been a recent initiative on the part of universities and research institutes to develop digital solutions for the agricultural industry, these developments require scaling and support from both businesses and the government.

Ukraine is attracting international companies offering advanced agrotechnologies, but the implementation
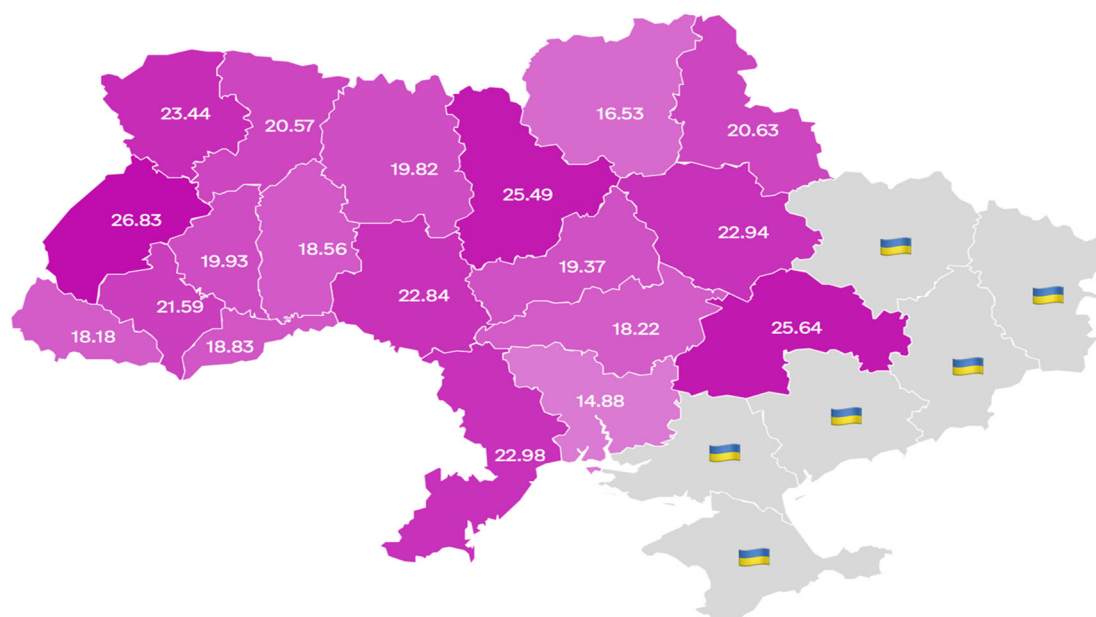
Figure 2. Digital Transformation Index of Hromadas of Ukraine as of July 2023

Source: (https://hromada.gov.ua/index)

of many projects is hampered by insufficient government support. In recent years, Ukraine has seen the emergence of agrotechnology startups offering innovative solutions such as mobile applications for farmers, platforms for data analysis and crop monitoring.

On 20 December 2023, the European Commission launched three new initiatives to promote scientific and innovation co-operation between the EU and Ukraine. These included the opening of a new Horizon Europe office in Kyiv, new activities by the European Innovation Council (EIC) to support the Ukrainian deep tech community, and a new Community Centre of the European Institute of Innovation and Technology (EIT). The European Innovation Council's EIC4Ukraine programme supports the Ukrainian deep tech community. The programme has allocated 20 million EUR to Ukrainian startups to help them grow and integrate into the European innovation ecosystem. The initiative, run by a European network of startup associations, will support at least 200 Ukrainian deep-tech startups with grants of up to 60,000 EUR each to further develop their innovation and business activities (European Commission. "Digital Innovation for Agribusiness: Programs and Initiatives"). As demonstrated in Figure 3, the graph presents a visual representation of the dynamics of loans provided by the FAO to Ukraine's agriculture, forestry, and fishing sectors from 2011 to 2023.

Digitalisation of Ukraine's agricultural sector is imperative for enhancing its efficiency, competitiveness, and sustainable development. However, for successful implementation, several issues must be addressed, including ensuring access to technologies, expanding

digital infrastructure, providing financial support to farmers, and training personnel. By leveraging global experience and adapting it to local conditions, Ukraine has the potential to become a leader in the use of digital technologies in agriculture. Table 5 presents the key aspects of the current state of digitalisation in Ukraine.
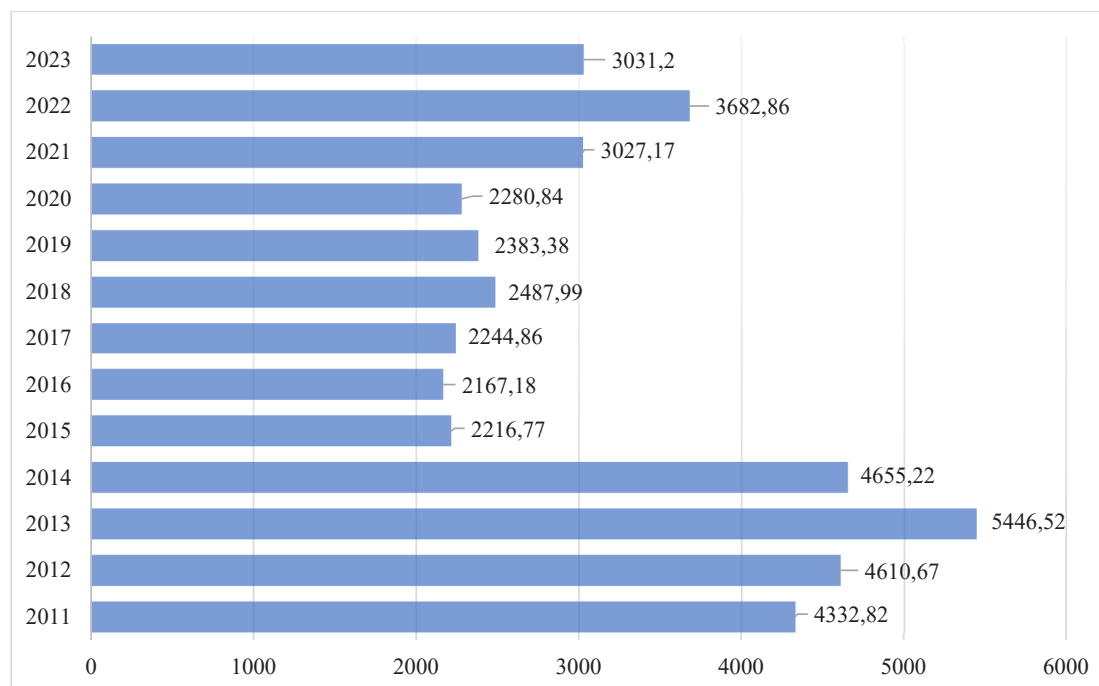
The digitalisation of Ukraine's agricultural sector presents significant opportunities, yet its successful implementation is contingent on government support, infrastructure development, and the integration of innovative solutions (Gorobets, Khomyakova, Starikovska, 2021).

The example of large agribusiness holdings demonstrates that technologies can significantly improve productivity, quality, and the competitiveness of Ukrainian agriculture.

6. Digitalisation as the Foundation for the Strategic Development of Agribusinesses

Digitalisation is not merely a tool for the modernisation of agribusinesses; it is also a strategic direction that shapes their ability to address contemporary challenges. The integration of digital technologies into production processes, management, and marketing has been demonstrated to facilitate sustainable development, enhance efficiency, and preserve competitive advantages. This is a vital condition for adapting Ukraine's agricultural sector to global changes and transitioning to an innovative development model.
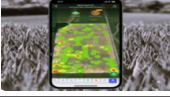
Figure 3. Volumes of loans to Ukraine's agriculture, forestry, and fishing sectors from FAO, 2011-2023, million USD

Source: (https://www.fao.org)

Table 5
Key aspects of the current state of digitalisation in Ukraine

Technology implementation		• Many large agricultural holdings (MHP, Kernel, Astarta) are actively implementing digital solutions for precision agriculture.
		• Small and medium-sized businesses are less active in using digital technologies due to financial and technical barriers.
State support		• In 2021, the Ministry of Agrarian Policy and Food of Ukraine introduced a program to develop digital services, including land registries and support for farmers through online platforms.
		• Creation of a National Geospatial Data Infrastructure (NGDI) to support land management.
Infrastructure		• The problem of access to high-speed Internet in rural areas remains relevant.
		• Active development of mobile applications for farmers, for example, GrainTrack, AgroOnline, AgroMeteo.

Source: compiled by the authors based on the research findings

In order to evaluate the efficacy of digitalisation as the basis for the strategic advancement of agribusinesses, economic and mathematical indicators can be utilised that encompass various dimensions of digitalisation, including productivity, profitability, resource efficiency, and investment utilisation. The proposal is to consider several key indicators.

1. Integral indicator of digitalisation efficiency, which allows assessing the overall effectiveness of digital solutions implementation, taking into account profits, costs and investments.

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Value *Eint > 1* demonstrates the effectiveness of digitalisation.

$$Eint = \frac{\sum_{i=1}^{n}(Pi - Ci)}{\sum_{i=1}^{n} * Ii} \tag{1}$$

where:

E_{int} – integral efficiency of digitalisation;

P_i – revenue growth from the implementation of digital technologies at the *i*-th stage;

C_i – costs associated with the implementation of digital technologies at the *i*-th stage;

I_i – investments in digitalisation at the *i*-th stage;

n – number of digitalisation stages.

2. The *economic efficiency of resource* use shows how effectively digitalisation helps to reduce resource costs while maintaining or increasing production volumes.

$$Eres = \frac{\Delta Q}{\Delta R} \tag{2}$$

where:

E_{res} – resource efficiency;

ΔQ – increase in production volumes (e.g., yield) thanks to digital technologies;

ΔR – reducing resource use (fertilisers, water, fuel, etc.) thanks to digital solutions.

3. The *return on investment in digitalisation* reflects the percentage of income generated by each hryvnia invested in digitalisation.

Value *ROI > 100%* indicates the effectiveness of investments.

$$ROI = \frac{(P - C)}{I} x 100\% \tag{3}$$

where:

ROI – return on investment in digitalisation;

P – total profit from digitalisation;

C – total costs of technology implementation;

I – amount of investment in digitalisation.

4. *Productivity gains from digitalisation* demonstrate the percentage increase in productivity after digitalisation compared to traditional methods.

$$\Delta Pprod = \frac{Qdig - Qtrad}{Qtrad} x 100\% \tag{4}$$

where:

ΔP_{prod} – productivity gains through digitalisation (%);

Q_{dig} – production volume after the introduction of digital technologies;

Q_{trad} – volume of production before the introduction of digital technologies.

5. The *digitalisation cost savings indicator* reflects the level of savings achieved through digital technologies.

Value *Scost > 0* indicates the positive effect of digitalisation.

$$Scost = \frac{Ctrad - Cdig}{Ctrad} x 100\% \tag{5}$$

where:

S_{cost} – cost savings through digitalisation (%);

C_{trad} – costs of traditional methods;

C_{dig} – costs after implementing digital technologies.

6. The *rate of return on digital investments* helps to determine how long it will take for investments in digitalisation to pay off. The lower the value of Tpayback, the faster the company receives financial benefits from digital technologies.

$$Tpayback = \frac{I}{(P - C)} \tag{6}$$

where:

$T_{payback}$ – payback period of digital investments (in years);

I – amount of investment in digitalisation;

*P* – annual profit from digitalisation;

C – annual digitalisation costs.

The provided indicators facilitate the evaluation of various dimensions of digitalisation effectiveness, including productivity, resource savings, investment profitability, and payback period. The application of these indicators enables agricultural enterprises to make strategically informed decisions regarding the implementation of digital technologies, to plan their development, and to achieve competitive advantages.

As a nation with a predominantly agricultural economy, Ukraine is obliged to assimilate itself into the global digital transformation processes if it is to consolidate its position within international markets. The application of global practices and the adaptation of innovative solutions will contribute to the sector's modernisation and long-term development.

7. Integration of Digital Solutions into Business Strategies and their Impact on Competitiveness

The integration of digital solutions into business strategies is a pivotal factor in their development within the context of the modern digital economy. The significance of this integration is evident in various aspects, as digital technologies allow businesses to adapt more effectively to market changes, innovate products and services, and offer unique solutions to consumers (Figure 4).

In addition, the automation of production and management processes helps to reduce costs, minimise the impact of the human factor and improve overall business efficiency. At the same time, digitalisation enables companies to address challenges such as globalisation, climate change, market instability and increasing environmental demands. By integrating digital solutions such as CRM systems, e-commerce platforms and personalised services, companies can better understand customer needs and deliver high levels of service.
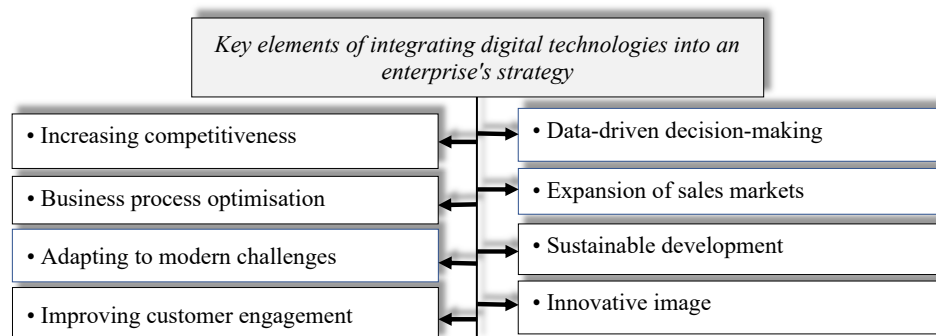
Figure 4. Key aspects of integrating digital solutions into the strategy of agricultural enterprises

Source: (Ievsieieva, Tsikalo, Mulyk, Udodova, Nazarenko, 2024)

Big data analytics, artificial intelligence and other digitalisation tools enable decision-making based on accurate forecasts and real performance metrics. The use of digital platforms provides access to global markets, facilitates the export of products and increases the competitiveness of companies on the international stage. Today, digital technologies contribute to optimising resources, reducing environmental impact and implementing environmentally friendly practices (Tomashuk, Susidenk, Burdyak, 2024). Companies that implement digital solutions are seen as modern and innovative, which helps to strengthen their reputation with customers, partners and investors. Integrating digital solutions into business strategies is crucial in today's business environment, which is characterised by intense competition, rapid change and the digitalisation of all aspects of life. Figure 5 illustrates the framework for developing the business strategy of an agricultural enterprise in the context of improving production activities.

Digital solutions are becoming not only a means of optimising operations, but also the basis for ensuring long-term growth and business sustainability. Today, digitalisation is a key factor in increasing the competitiveness of companies, as it improves efficiency, flexibility and adaptability to rapidly changing market conditions (Kuznetsova, Gorbatiuk, Mulyk, Piskun, Pashchenko, Hridin, 2021).

In the agricultural sector, digital technologies are helping businesses to remain competitive in both domestic and global markets.

Digital tools, including online platforms, e-commerce, and social media, have enabled companies to expand their presence in global markets. The accessibility of digital solutions has enabled small and medium-sized enterprises to compete on an international scale.

Modern technologies, including robotic systems, cloud services and automation platforms, enable companies to optimise processes and reduce production, maintenance and management costs. This creates a competitive price advantage in the marketplace.

Digitalisation makes companies more agile and responsive to changing consumer demands and market conditions. Big data analytics and artificial intelligence tools make it possible to quickly identify trends and adapt strategies.

CRM systems, chatbots and personalised services help companies better understand customer needs and improve service quality, strengthening customer loyalty and fostering long-term relationships.

The integration of advanced technologies, including the Internet of Things (IoT), blockchain, augmented reality (AR), and artificial intelligence (AI), has engendered prospects for the conception of innovative products and services that are in accordance with contemporary consumer requirements (Rudenko, 2019). Digitalisation technologies enhance resource efficiency, for example, through inventory management systems or precision farming in the agricultural sector. This, in turn, has the potential to reduce costs and enhance environmental performance.

The implementation of digital solutions, such as blockchain technology, has been demonstrated to enhance transparency within supply chains, thereby fostering increased consumer confidence in brands. This is of particular relevance to companies in the food, pharmaceutical, and agricultural industries. The development of Software as a Service (SaaS) platforms has made digital solutions accessible even to small enterprises, thereby fostering high levels of competition in markets regardless of company size.

In the contemporary business environment, digitalisation enables enterprises to adopt eco-friendly practices, including the reduction of waste through process optimisation, thereby conferring a substantial competitive advantage (Kaletnik, Lutkovska, 2020). As illustrated in Figure 6, the key elements influencing the competitiveness of agricultural companies through digitalisation are outlined.

It is imperative for enterprises to ensure the security of their digital systems against cyber threats. This necessitates the allocation of resources towards security measures, thereby fostering trust among customers
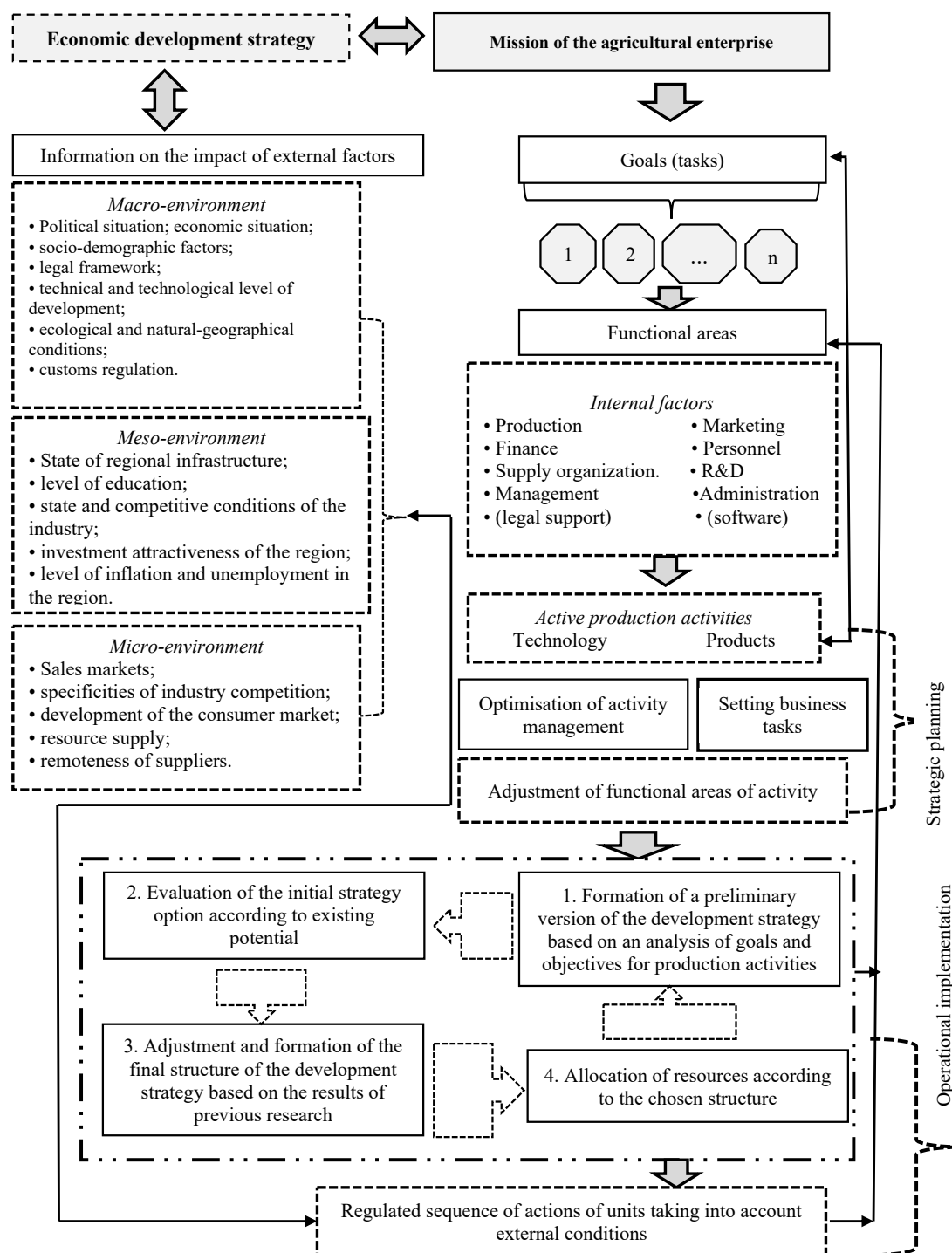
Figure 5. Scheme of forming the strategy of economic development of an agricultural enterprise in the context of intensification of production activity

and partners. The present impact of digitalisation on competitiveness is defined by speed, adaptability, and innovation. Figure 7 presents the share of the digital economy in Ukraine's GDP from 2019 to 2022, along with projections for 2025-2032, which indicate an upward trend.

It is recommended that an analysis of the competitiveness indicators of agricultural enterprises be conducted, with said indicators being analysed based on the key factors influencing their operational efficiency and stability.

1. *Determination of the overall competitiveness of the enterprise,* which takes into account the profitability of products (the difference between the selling price and the cost price) and sales volume, which determines the company's market share.

Key factors of digitalisation's impact on competitiveness

- Globalisation of business and expansion of markets;
- automation and cost reduction;
- speed of adaptation to market changes;
- improving the quality of interaction with customers;
- innovation as a source of competitive advantage;
- precision of resource management;
- transparency and trust;
- competition through the availability of digital technologies;
- environmental competitiveness;
- cybersecurity as a strategic challenge.

Figure 6. Key elements of the impact of digitalisation on the competitiveness of agricultural companies

Source: (Honcharuk, Tomashuk, 2022)
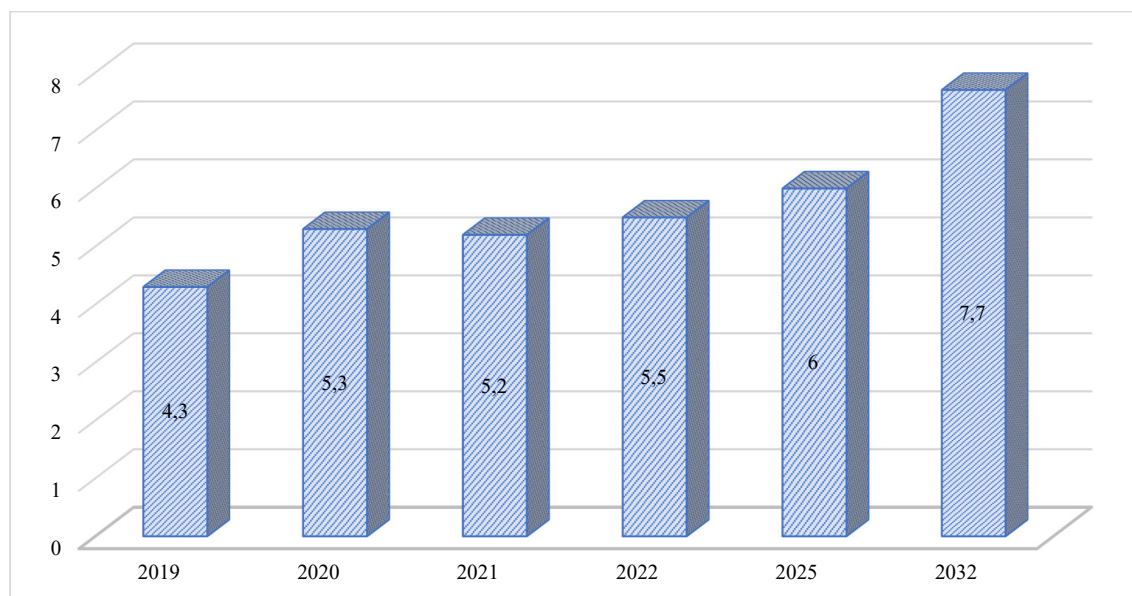
Figure 7. Share of the digital economy in Ukraine's GDP, 2019-2022, forecast for 2025-2032, %

Source: (Draft Recovery Plan for Ukraine)

$$Oci = \frac{Pm - Cp}{Pm} \times Q \qquad (7)$$

where:

O_{ci} – overall competitiveness index;
P_m – market price of the product;
C_p – cost of production per unit of product;
Q – volume of products sold.

2. *Resource efficiency indicator* demonstrates how efficiently a company uses resources. The more output produced per unit of cost, the higher its competitiveness.

$$Er = \frac{Gross\ product\ volume\,(Q)}{Total\ resource\ costs\,(R)} \qquad (8)$$

where:

E_r – resource efficiency;

Q – volume of gross output in physical or value units;
R – total resource costs (land, labor, energy, etc.).

3. *The innovation competitiveness indicator* emphasises the importance of innovation. If investments lead to improved quality and higher product prices, a company becomes more competitive.

$$Cin = \frac{Iimplem}{Ci} \times \Delta P \qquad (9)$$

where:

C_{in} – innovation competitiveness indicator;
$I_{implem.}$ – investments in innovation implementation;
C_i – cost of production after the introduction of innovations;
ΔP – increase in product price due to improved quality.

4. *Market competitiveness indicator* illustrates the company's market share. The higher the share, the higher the competitiveness.

$$Cmark = \frac{Scompan}{Smark} \qquad (10)$$

where:

C_{mark} – the company's market share (market competitiveness);

S_{compan} – sales volume of the company's products;

S_{mark} – total market volume.

5. *Comprehensive competitiveness indicator* takes into account several important aspects of the enterprise's activities and allows to obtain an integrated indicator of competitiveness.

$$C_{compr} = W_1 \cdot O_{ci} + W_2 \cdot E_r + W_3 \cdot C_{in} + W_4 \cdot C_{mark} \qquad (11)$$

where:

C_{compr} – comprehensive competitiveness indicator;

W_1, W_2, W_3, W_4 – weighting factors of each component (determined by experts depending on market conditions).

The implementation of digital technologies is not only desirable but also strategically essential for maintaining market positions (Honcharuk, Tomashuk, 2022). Companies that fail to acknowledge these trends risk diminishing their competitive advantages and becoming lagging behind market leaders.

8. Conclusions

Digital technologies are becoming a strategic driver for the innovative development of agricultural enterprises, enabling the optimisation of production processes, increased productivity, and enhanced competitiveness within the agricultural sector. The integration of technologies such as precision farming, the Internet of Things (IoT), artificial intelligence (AI), and blockchain has been shown to facilitate more efficient resource utilisation, cost reduction, and minimisation of human influence. The utilisation of big data analytics systems, the automation of accounting processes, and the employment of digital platforms for management support facilitate informed decision-making, thereby enabling businesses to adapt to contemporary market conditions.

Key barriers to digital transformation include insufficient funding, limited digital literacy among staff and underdeveloped infrastructure in many regions. Overcoming these challenges is essential for the widespread adoption of digital tools. Digitalisation increases the resilience of the agricultural sector, enabling it to respond to global challenges such as climate change, resource scarcity and the growing demand for high-quality food. The availability of digital technologies creates new opportunities for small- and medium-sized agricultural enterprises, enabling them to compete with large corporations and access global markets.

Digital innovations also promote the adoption of environmentally friendly practices, such as precision agriculture and the rational use of natural resources, in line with the principles of sustainable development. The successful implementation of digital solutions requires effective government policies, investment in infrastructure and the development of digital literacy programmes in agriculture. The digitalisation of the agricultural sector is a crucial element for its transformation and innovative development. The active adoption of digital technologies will enhance the competitiveness, efficiency and resilience of agricultural enterprises in the global environment.

References:

Yaroschuk, R. (2024). The impact of digital technologies on increasing the efficiency of agricultural production. *Economy and Society*, Vol. 68. DOI: https://doi.org/10.32782/2524-0072/2024-68-58

Gorobets, N. M., Khomyakova, D. O., & Starikovska, D. O. (2021). Prospects for the use of digital technologies in the activities of agricultural enterprises. *Effective economy,* Vol. 1. DOI: https://doi.org/10.32702/2307-2105-2021.1.90

Rudenko, M. V. (2019). The impact of digital technologies on agricultural production: a methodological aspect. *Scientific notes of the V. I. Vernadsky TNU. Series: Economics and Management*, Vol. 30 (69), p. 6. DOI: https://doi.org/10.32838/2523-4803/69-6-28

Yurchuk, N. P., & Kiporenko, S. S. (2022). Features of the use of digital technologies in agribusiness. *Eastern Europe: economics, business and management. Series: economics and enterprise management,* Vol. 3 (36), p. 109–116. DOI: https://doi.org/10.32782/easterneurope.36-17

Samoilenko, D. (2024). Peculiarities of the application of digital technologies in agribusiness. *Economy and Society,* Vol. 64. DOI: https://doi.org/10.32782/2524-0072/2024-64-148

Food and Agriculture Organization of the United Nations (FAO). "Digitalization in the Agricultural Sector: Global Trends". Available at: https://www.fao.org

World Bank. "Digital Technologies for Agricultural Development in Developing Countries". Available at: https://www.worldbank.org

European Commission. "Digital Innovation for Agribusiness: Programs and Initiatives". Available at: https://eufordigital.eu/uk/european-commission-launches-three-initiatives-supporting-ukrainian-researchers-and-innovators/

Draft Recovery Plan for Ukraine. Materials of the Working Group "Recovery and Economic Development". Available at: https://www.kmu.gov.ua/storage/app/sites/1/recoveryrada/ua/economic-recovery-and-development.pdf

Tarasovsky, Yu. (2024). Forbes. Available at: https://forbes.ua/news/pryami-zbitki-agrarnogo-sektora-ukraini-cherez-viynu-perevishchili-80-mlrd-kse-agrotsentr-21022024-19364

Index of digital transformation of hromadas of Ukraine. Available at: https://hromada.gov.ua/index

Innovation hubs in Ukraine, EU "Digital Europe". Available at: https://khmnu.edu.ua/innovaczijni-haby-v-ukrayini-yes-czyfrova-yevropa/

Koliadenko, S., Andreichenko, A., Galperina, L., Minenko, S., & Kovylina, M. (2020). Analysis and forecasting of Ukrainian agrarian exports to the EU countries. *Agricultural and Resource Economics : International Scientific E-Journal,* 3, 6: 29–47.

Ievsieieva, O., Tsikalo, Y., Mulyk, T., Udodova, Y., & Nazarenko, O. (2024). Adapting accounting to the digital age: The urgent need for new regulatory standards. *Amazonia Investiga,* 13, 83: 89–99. DOI: https://doi.org/10.34069/AI/2024.83.11.7

Kaletnik, G., & Lutkovska, S. (2020). Innovative Environmental Strategy for Sustainable Development. *European Journal o f Sustainable Development,* 9, 2: 89–98.

Soloviova, O., Krasnyak, O., Cherkaska, V., & Revkova, A. (2022). Development of International Corporate Social Responsibility in Agribusiness. *Economics Ecology Socium,* 6, 4: 51–64. DOI: https://doi.org/ 10.31520/2616-7107/2022.6.4-5

Kuznetsova, I., Gorbatiuk, V., Mulyk, T., Piskun, A., Pashchenko, O., & Hridin, O. (2021). Peculiarities of formation of competitive strategy of the enterprises of flour-milling branch of Ukraine. *Independent Journal of Management & Production,* 12 (6): 516–539.

Chikov, I., Radko, V., Marshalok, M., Tepliuk, M., Petrenko, O., Sharko, I., & Sitkovska, A. (2022). Economic development of agricultural food enterprises on an innovative basis. *Financial and credit activity-problems of theory and practice,* 1 (42): 98–106.

Honcharuk, I. V., & Tomashuk, I. V. (2022). Formation of a strategy for the economic development of an agricultural enterprise to increase its competitiveness. *Economics, finance, management: current issues of science and practice,* 4 (62): 7–24. DOI: https://doi.org/ 10.37128/2411-4413-2022-4-1

Sydoruk, B., Sava, A., Korzhenivska, N., Zdyrko, N., & Khaietska, O. (2021). Optimization of economic and ecological components of using agricultural lands for balanced land use and rural areas development. *Independent Journal of Management & Production,* 12, 6: 417–430. DOI: https://doi.org/ 10.14807/ijmp.v12i6.1767

Yarmoliuk, O., Abramov, A., Mulyk, T., Smirnova, N., & Ponomarova, N. (2024). Digital technologies in accounting and reporting: benefits, limitations, and possible risks. *Amazonia Investiga*, 13, 74: 323–333. DOI: https://doi.org/10.34069/AI/2024.74.02.27

Palamarchuk, V., Honcharuk, I., Honcharuk, T., & Telekalo, N. (2018). Effect of the elements of corn cultivation technology on bioethanol production under conditions of the right-bank forest-steppe of Ukraine. *Ukrainian Journal of Ecology*, 8 (3): 47–53.

Tomashuk, I. V., Susidenk, Yu. V., & Burdyak, M. I. (2024). Global trends in the development of the world economy in the context of digitalization: an ecological aspect. *Business Navigator*, 2(75): 15–28. DOI: https://doi.org/10.32782/business-navigator.75-3

Network Readiness Index 2024. Available at: https://networkreadinessindex.org/countries/