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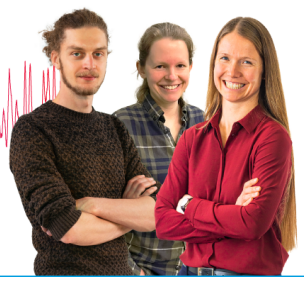

Digital Technologies in Agriculture: Befits and Costs at Different Levels

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Abstract. Digital technologies in agriculture are revolutionizing how firms grow and harvest crops. Using digital tools, farmers can increase their yields, reduce waste, and ultimately feed a growing population. The importance of studying agriculture digitalization has significantly increased in recent years. The agriculture industry faces many challenges, from climate change and water scarcity to labor shortages and market volatility. These challenges can make it difficult for farmers to maintain profitability and sustainability. However, digital technologies offer solutions to these challenges.

Keywords: technology, agriculture, the products, management efficiency.

INTRODUCTION

Digital technologies in agriculture are revolutionizing how firms grow and harvest crops. Using digital tools, farmers can increase their yields, reduce waste, and ultimately feed a growing population. The importance of studying agriculture digitalization has significantly increased in recent years. The agriculture industry faces many challenges, from climate change and water scarcity to labor shortages and market volatility. These challenges can make it difficult for farmers to maintain profitability and sustainability. However, digital technologies offer solutions to these challenges.

METHODS AND MATERIALS

The study aims to investigate probable benefits and costs for subjects of the economy at different levels, such as micro-level, macro-level, and global level. The study results were obtained based on assumptions and analysis of foreign literature. The study used monographic, abstract-logical, comparative, and other methods [1].

RESULTS AND DISCUSSION

Figure 1 represents the key components of digitalization in agriculture according to the author's definition of "digital economy".

Based on the analysis of the opinions of scientists [5, 17] in the field of digitalization, the author's approach to the definition of the term "digital economy" has been developed. It was revealed that the digital economy is a system of social, economic, and technological relations between the state, business community, and civil data, functioning in the global information space using using network digital technologies, generating new digital types, forms of production, promotion of products to the consumer and services that lead to innovative changes in management practices and technologies to improve the efficiency of socioeconomic processes in the state.

Digital technologies in agriculture offer a multitude of benefits for farmers. With the help of precision

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agriculture, sensors and IoT, drones, robotics, big data and analytics, blockchain, and smart farming, farmers can optimize their operations, increase yields, reduce waste, and improve sustainability [4]. These technologies enable farmers to make data-driven decisions, automate tasks, and access real-time information about their crops.

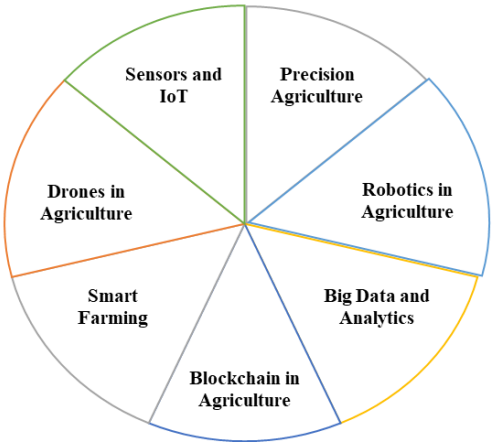

FIGURE 1. Components of agriculture digitalization.

Moreover, digital technologies allow farmers to save time and money by reducing labor costs and improving efficiency. They also provide greater transparency and traceability, which is increasingly important for consumers who want to know where their food comes from and how it was produced. By embracing these technologies, farmers can stay competitive and meet the growing demand for food in a rapidly changing world.

TABLE 1. Effects of digital technologies adoption in agriculture.

Technology	Micro-level	Macro-level	Global level	Benefits
Precision Agriculture	Higher quality crops Profits increase	Increased efficiency in agriculture	Improved sustainability	Optimize crop yields and reduce waste
Sensors and IoT	Detect issues	Better resource management	Reduced environmental impact	Higher crop yields
Drones in Agriculture	Provide real-time data on crop health and growth	Decisions about irrigation, fertilization, and pest control	Reduced environmental impact	Reducing the time and resources used in production
Robotics in Agriculture	Automate tasks and increase productivity	Side effects on the labor market	Structural unemployment	Freeing up time for farmers to focus on other aspects of their business
Big Data and Analytics	Farmers can make more informed decisions	Important factors that affect yield and profitability	Reduce waste, optimize resource use, and minimize environmental impact	Using predictive analytics, farmers can avoid overproduction and underproduction
Blockchain in Agriculture	Farmers can ensure that their products are authentic, safe, and of high quality	Track products from farm to table, ensuring fair prices and reducing the need for intermediaries	Resistant to fraud and hacking, providing an added layer of security for sensitive data	Reduce food waste and increase efficiency in supply chain management
Smart Farming	Farmers can make informed decisions about when to plant, irrigate, fertilize, and harvest their crops	More accurate predictions about crop yields and market demand	Minimize environmental impact	Increase productivity, reduce costs, and

Precision agriculture is a farming management concept that uses technology to optimize crop yields and reduce waste [22]. Farmers can make more informed decisions about planting, fertilizing, and harvesting crops by collecting data on soil conditions, weather patterns, and other factors. This technology can benefit farmers in several ways, including increased efficiency, reduced costs, and improved sustainability. Precision agriculture can also help farmers produce higher-quality crops and increase their profits.

Sensors and IoT (internet of things) are revolutionizing how we approach agriculture. Farmers can make more informed decisions that lead to higher crop yields and better resource management by collecting data on everything from soil moisture to temperature. These sensors can be placed throughout fields and connected to a central network, allowing for real-time monitoring and analysis. With this technology, farmers can detect issues early on and take action before they become major problems. The result is increased productivity and reduced waste and environmental impact.

Using drones in agriculture can improve efficiency by reducing the time and resources required for manual inspections. They can also provide real-time crop health and growth data, allowing farmers to make informed decisions about irrigation, fertilization, and pest control. Robotics is revolutionizing the agriculture industry. With the help of robots, farmers can automate tasks and increase productivity like never before. From planting to harvesting, robots can do it all with precision and speed.

Big data and analytics play a crucial role in modern agriculture by providing farmers real-time insights into crop health, weather patterns, soil quality, and other important factors affecting yield and profitability [9]. Farmers can make more informed decisions about when to plant, water, fertilize, and harvest their crops by collecting and analyzing vast amounts of data from sensors, drones, satellites, and other sources. In addition to improving crop yields, big data and analytics can help farmers reduce waste, optimize resource use, and minimize environmental impact. For example, by using predictive analytics to anticipate weather patterns and market demand, farmers can avoid overproduction and underproduction, which can lead to food waste and financial losses. By leveraging these technologies, farmers can proactively manage their operations and stay ahead of the curve in an increasingly competitive industry.

Blockchain technology can improve the agriculture industry by providing a secure and transparent way to track products from farm to table. Using blockchain, farmers can ensure that their products are authentic, safe, and high quality. This technology can also help reduce food waste and increase efficiency in supply chain management. In addition, blockchain can create smart contracts between farmers and buyers, ensuring fair prices and reducing the need for intermediaries. The decentralized nature of blockchain also makes it resistant to fraud and hacking, providing an added layer of security for sensitive data.

Smart farming can benefit farmers in many ways. It can help them increase productivity, reduce costs, and minimize environmental impact [10]. For example, by using precision irrigation systems that deliver water only where needed, farmers can save water and energy while improving crop yields. Using drones to monitor crops, they can detect early signs of disease or pest infestation and take action before it spreads. And by using big data analytics to analyze soil samples and weather patterns, they can make more accurate predictions about crop yields and market demand.

Table 2 shows areas of innovation in the agricultural sector at the macro level. Some key effects need to be explained at these levels, too.

One trend that we can expect to see is the increased use of artificial intelligence and machine learning to help farmers make better decisions. These technologies will be able to analyze data from sensors, drones, and other sources to provide insights into crop health, soil quality, and weather patterns. This will enable farmers to optimize their operations and increase yields.

Digital technologies in agriculture offer a multitude of benefits for farmers. With the help of precision agriculture, sensors and IoT, drones, robotics, big data and analytics, blockchain, and smart farming, farmers can optimize their operations, increase yields, reduce waste, and improve sustainability [11]. These technologies enable farmers to make data-driven decisions, automate tasks, and access real-time information about their crops. Moreover, digital technologies can help farmers save time and money by reducing labor costs and improving efficiency. They also provide greater transparency and traceability, which is increasingly important for consumers who want to know where their food comes from and how it was produced. By embracing these technologies, farmers can stay competitive and meet the growing demand for food in a rapidly changing world.

One of the main barriers to adopting digital technologies in agriculture is farmers' lack of knowledge and awareness [21]. Many farmers are unfamiliar with the latest technologies and do not understand how they can benefit their operations. This can lead to resistance to change and reluctance to invest in new technologies. Another barrier is the cost of implementing digital technologies. Many farmers operate on tight budgets and may not have the resources to invest in expensive equipment or software. Additionally, there may be concerns about the return on

investment and whether the benefits of the technology will outweigh the costs.

TABLE 2. Areas of digital and technological innovation in agricultural sector.

Area	Characteristics
New manufacturing system technologies	– innovations in the field of water and soil conservation; – technologies in the field of aquaculture and hydroponic farming; – digital technologies designed for the development of agricultural farms
Mechanization, automatization, and robotization of workplaces	– workplace automatization; – application of an intelligent irrigation system; – introduction of advanced technologies for the cattle and dairy industry
Genetics and protection of plants and animals	– seed genetics (biotechnology); – fertilizers and biological products (biostimulants, biopesticides, biofertilizers); – genetics of animals and fishes; – animal nutrition and health
Big Data & Precision Agriculture	– soil analysis and environmental assessment; – drones and satellite imagery; – remote sensors and geo-referenced monitoring; – integrated hardware and software solutions; – data analysis and technological support for managerial decision-making
Management software and information services for agricultural producers	– business management software; – logistic information

Implementing digital technologies in agriculture can require a significant upfront investment, but the long-term benefits often outweigh the costs. When considering the return on investment (ROI) of implementing digital technologies in agriculture, it's important to factor in the financial and environmental and social benefits. For example, using blockchain technology to improve traceability and transparency can help build consumer trust and increase sales. Adopting sustainable practices with the help of digital technologies can help preserve natural resources for future generations.

Collaboration and partnerships are essential in implementing digital technologies in agriculture. With the complexity of these technologies, it is important to have a diverse team with different skill sets working together toward a common goal. This can include farmers, technology experts, researchers, and government officials. By combining their expertise, they can create innovative solutions that address the challenges faced by the agriculture industry.

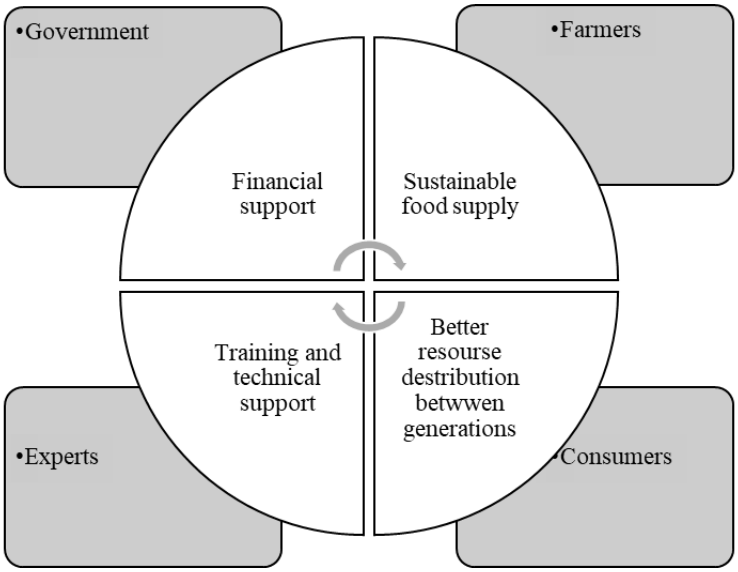

FIGURE 2. Partnership for sustainable agriculture.

Partnerships also play a crucial role in ensuring the sustainability of these technologies. Farmers can access the resources and support needed to implement these technologies effectively by partnering with organizations that share the same values and goals. This includes access to funding, training, and technical support. Collaboration and partnerships are to unlock the full potential of digital technologies in agriculture. The government has taken an active role in promoting the adoption of digital technologies in agriculture. Through various initiatives, they have provided funding and support to farmers who wish to implement these technologies on their farms.

To fully take advantage of the benefits of digital technologies in agriculture, it is important for farmers and other stakeholders to receive proper training and education. This includes understanding the technical aspects of the technology as well as how to integrate it into their existing operations. Additionally, training and education can help farmers develop the necessary skills to analyze data and make informed decisions based on the insights provided by digital technologies. This can lead to improved productivity, efficiency, and profitability.

Although the benefits of agricultural digitalization are evident, this process is connected with some problems and losses in the short run.

As with any technology, there are concerns about security and privacy regarding digital technologies in agriculture. Farmers may worry about the safety of their data or the possibility of cyber attacks. However, it's important to note that many digital technologies have built-in security features, such as encryption and multi-factor authentication. Additionally, farmers can take steps to protect their data by using secure passwords and regularly updating their software.

Privacy is another concern, as some farmers may be hesitant to share their data with third-party providers. However, many digital technologies allow farmers to control who has access to their data and how it is used. Furthermore, sharing data can benefit farmers by providing valuable insights and recommendations for improving their operations.

However, digitalization has both advantages and disadvantages. One of the latter may be the problems of the national economic security of the digital society. Analysis of literary sources allows you to systematize digital threats and challenges that exist and affect them (Fig. 3).

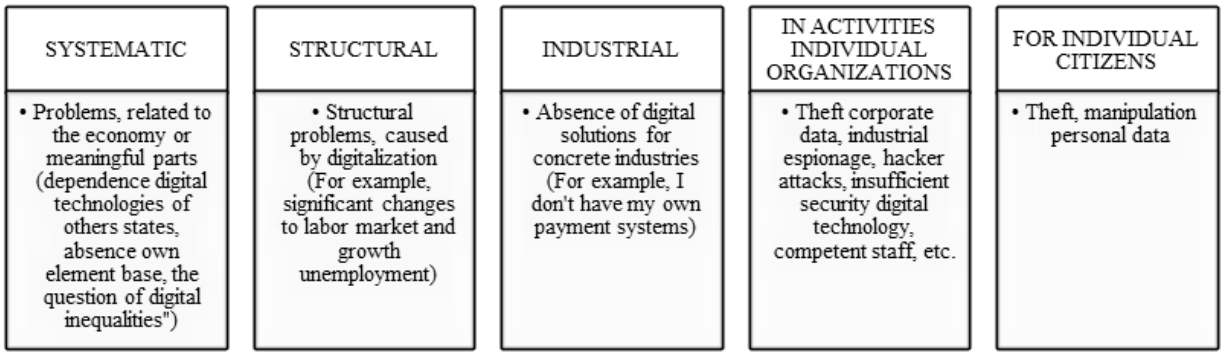

FIGURE 3. Problems of national economic security of digital society.

Summarizing the above, it can be noted that every year, the number of problems will increase due to the increasing use of digital technologies in various spheres of the economy of the Republic of Belarus. Due to this, we propose creating a mechanism for smoothing the impact of digital transformation on national security.

When developing it, it is necessary to adhere to generally accepted principles:

- consistency - this means that a good structure is consistent when knowledge of the system allows you to predict the opposite;
- orthogonality - it is required that the functions be independent of each other friend and were asked separately;
- compliance - the structure should include only those functions that meet the essential requirements of the system;
- economy - not a single part of the description of the structure is in any way oak lyes another;
- transparency - the user must know the results found during execution functions;
- generality - a new function should be introduced so that it corresponds to as many goals as possible;
- openness - the user should be able to specify the specification and content of the system functions in working with it;
- completeness - the specification of functions must meet all the requirements and the wishes of the user.

Digital agriculture technologies can potentially revolutionize food production on a global scale. With a growing population and increasing demand for food, it is more important than ever to find innovative solutions to feed the world [16]. Digital technologies can help increase crop yields, reduce waste, and improve sustainability, ultimately leading to more efficient and effective food production. This benefits individual farmers and has a global impact by helping to address food security and reduce hunger around the world.

Economic science has long substantiated the important role of the state in stimulating collective actions. One of the functions is the production and distribution of public goods, the production and distribution of which cannot be completely fulfilled by the market. Traditionally, a global public good (GPG) is a good that has the following three properties [1]:

– non-competitiveness. The consumption of this good by the agent does not reduce the amount available to other agents.

– non-excludability. The costs of excluding anyone from consuming the good are high.

– the good is available all over the world.

This concept is an extension of the classical concept of the public good of the American economist P. Samuelson on the economics of globalization. W. Nordhaus identified similar features in global public goods [7].

In literature, various groups of global public goods are distinguished. We have proposed the following classification of GPG (Table).

TABLE 3. Groups of global public goods.

Groups	Characteristics	Objects
Economic	The production decision is made not everyone interested in it parties, and its consumption becomes a completely public distribution of benefits among consumers - equal	1) Liberal trade mode 2) Financial and economic stability 3) Providing global resource economy
Social and political	«Pure» global public good. Non-excludable and non-competitive	1) Peace and security 2) Human rights 3) The rule of law and social order 4) Disease control
Infrastructural	Characterized by both free and limited access, the principle of «non-excludability» is stated at the planetary scale	1) Global system air navigation 2) Internet 3) Knowledge
Environmental	Systems used as public consumer goods and to dispose of human waste generally	1) Ocean 2) Atmosphere, climate sustainability 3) Biodiversity

Economic GPG is a liberal trade regime, financial and economic stability, ensuring a sufficient supply of resources (for example, oil).

Social and Political GPGs – Ensuring International Peace and security, providing mediation services in settlement conflicts, upholding human rights, upholding the rule of law and order, fighting disease, and raising medical standards. Providing these benefits is impossible without creating effective institutions at all levels of global governance.

Infrastructure GPGs – Benefits resulting from combining efforts and standardizing the benefits created in different countries. For example, this is a global air navigation system, physical and virtual Internet infrastructure, and knowledge in the broadest sense of the word.

Environmental GPGs are ocean, atmosphere, biological diversity, and climate stability.

R.A. Musgrave divided global public goods into two large groups [6]: «The first includes the so-called finite public goods that directly satisfy certain needs of the global community (e.g., keeping the peace, protecting the environment and cultural heritage of mankind). The second - is intermediate global public goods, which are sets rules for the implementation and regulation of certain types of activities in the international arena».

L.N.Shcherbakova proposes to divide the GPG into three groups according to the criterion of their formation [23]:

– «the first group should include natural global public goods, such as the Earth's atmosphere and the high seas. Boons of this kind initially act as external about nation-states, but the problem of abuse of global environmental benefits has given rise to the need for regulation of their use, including at the national level;

– the second type of goods includes goods arising from human activity. Modern conditions include resources, knowledge, information and transport communications, and international law. The specificity of the resources "knowledge" and "information" is quite extensive; however, a significant role in it is given to their global character;

– in the content of the third group of global public goods included political benefits such as financial stability, peaceful coexistence, the fight against infectious diseases, etc.».

As far as the Internet is among infrastructural GPGs, it can be better if more users benefit from its use. 4.95 billion people worldwide use the Internet in January 2022 – equivalent to 62.5 % of the world's total population. What's more, fewer than 3 billion people worldwide don't use the Internet, marking another important step towards universal accessibility.

Here are the key figures you need to understand the use of the Internet today. There are 4 key drivers of internet use worldwide – global population, number of mobile users, social media users, and Internet access. Internet access plays a key role in the digitalization of agriculture. Moreover, without it, this sphere of the economy can not be improved and modernized.

As it was stated, rising demand for the Internet improves the quality of this good itself. Rising numbers of a global population of mobile users, social media, and internet users promote worldwide access, and this good naturally becomes global. Recent efforts of Elon Musk's company, SpaceX, can really ensure non-excludability at the planetary scale.

Rising world demand for the Internet can be explained by its effect on transaction costs. Internet use simplifies many processes of consuming and producing goods [21]. Digitalization promotes high-speed access to supplier search, GIS, maps, law databases, etc. Information becomes accessible anytime and anywhere. So, the internet diminishes two negative factors of a market economy – information asymmetry and transaction costs.

Transaction costs theory adopts the now standard assumption that asymmetric information between parties to a transaction – such as one party not knowing if the other party may act opportunistically and defraud the first party – can impede the creation of gains from trade. If the perceived threat of fraud is too high for either party, they may decide not to engage in a transaction.

Indeed, it has been argued that a reputation of trustworthiness can be an important source of competitive advantage. The potential risk of fraud is particularly acute in online settings, where buyers and sellers do not interact face-to-face. However, the frequency of digitally mediated transactions, coupled with digital trace information about the transacting parties, means that reputations can be developed for each party, which in turn helps mitigate the concerns from asymmetric information.

The consumer becomes more informed using the internet while searching suitable transaction terms [2]. However, transaction costs may rise in some cases due to the lack of consumer time spent searching. But generally, the Internet is more likely to change production and consumption processes positively. Even governments are using and providing internet-based services.

Despite high rates of internet use, there are still areas of the world without free access to this global public good. Data reveal that the number of people who remain "unconnected" to the internet has now dropped below 3 billion for the first time. This marks a significant factor in scoring equal digital access and has particular relevance as the role of connected devices has moved from luxury to lifeline, especially during the COVID-19 pandemic.

All the above shows that the Internet's demand doesn't meet its supply. Lack of supply can be provided by improving living conditions in poor countries in general. However, the Internet is different from other economic issues because there is no workable mechanism for resolving these issues effectively. Markets routinely fail to solve the problems caused by global public goods. The inefficiencies are the greatest for global public goods, whose benefits are spread most widely across space and time [3].

As W. Nordhouse states [7], one of the distinguishing features of most global public goods is that they are generally "stock externalities." This term means that their impact depends upon a stock of a capital-like variable that accumulates over time.

According to D. Brito, just as global public goods involve externalities over space, in the case of stock public goods, they involve externalities over time. While markets are linked over time through capital markets, there is no similar linkage over time for stock global public goods [19]. No market today accurately reflects the impact of the Internet a century from now.

Internet usage produces positive and negative externalities; thus, the main policy challenge is enhancing the positive externalities and economies of scale while preventing the negative externalities, thus achieving net positive gains. Governments are privileged to observe the overall effect of market interactions in society, coordinate multi-

stakeholder solutions, and take actions that make society better off.

Cyber-security threats are the foremost negative externality of the Internet. Cybercrime, cyber-warfare, cyber-terrorism, cyber-espionage, and privacy breaches increasingly disrupt communications, businesses, finance, commerce, and public services and present severe threats to global political stability [18]. These threats undermine the use and supply of the Internet by reducing trust in online services and increasing costs to people, businesses, and governments. Suppose developing countries, in particular, do not effectively build strong foundations and institutions for providing the Internet and mitigating cyber threats. In that case, they may become the main sources of attacks and global threats to cyber-security.

The Internet presents social and economic attributes of a global public good [20]. The social attributes reflect society's recognition that the Internet is a fundamental driver of socioeconomic development and should be provided for everyone. Governments should promote the efficient provision of the Internet as a public good at the national level to foster economic growth and social inclusion and at the international level to establish common standards and a minimum level of Internet access for all and to reduce the digital divide. The economic attributes manifest themselves in the global underuse and undersupply of the Internet, the inequality in access, market failures, and the transnational positive and negative externalities.

CONCLUSIONS

In conclusion, digital technologies have the potential to revolutionize the agriculture industry. From precision agriculture and sensors to drones and robotics, these technologies offer solutions to many of the challenges faced by farmers today. Big data analytics, blockchain, and smart farming are important tools that can help improve transparency, sustainability, and productivity.

While there may be barriers to adoption, such as cost and lack of education or training, farmers need to embrace these technologies to stay competitive and meet the growing demand for food. Collaboration and partnerships will also be key in implementing these technologies and addressing any concerns related to security and privacy.

Digitalization of agriculture has benefits and costs at the micro-level, macro-level, and global levels. In the short run, costs remain higher than benefits for farmers, but that changes in the long-run. To develop sustainable agriculture and food production, the collective actions of stakeholders need to be stimulated. Global food security and sustainable resource management result from agriculture digitalization, which is correlated with rising Internet access.

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