Economic Efficiency from Digitization in Agriculture

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Abstract: Agriculture is a vital sector of material production, designed to satisfy the needs of the population for food, and the food and processing industry for raw materials. A long-term goal for the development of the food segment is to ensure national food security and realize the export food potential of the principles of sustainability and innovation. Digitalization in agriculture has the potential to address numerous challenges, but its success depends on strategic implementation with foresight and adaptability. By leveraging Internet of Things (IoT) technologies and developing cyber-physical systems, the agricultural sector can enhance efficiency, sustainability, and resilience. The created digital models of each resource must have a hierarchical structure and cover all levels of management from specific industries to the decision-making system of the country's political leadership. Digital agriculture requires the attraction of deeper and more effective technologies. Technological processes in agriculture differ significantly from those in industry, as they are closely linked to biological elements such as plants, animals, soil, and the surrounding ecological environment. These natural components introduce unique challenges and require specialized approaches to ensure sustainable and efficient agricultural practices.

Key-Words: Economic Efficiency, Digitalization, Agriculture, Production Potential, Agricultural Sector, Digital Agriculture, Food Segment

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1 Introduction

Agriculture is a vital branch of material production, designed to satisfy the needs of the population for food, and the food and processing industry for raw materials. The development of agriculture is largely determined by the development of the industry that produces agricultural and land improvement equipment, fertilizers, and means for their application. In turn, agriculture, as a supporting industry, has a significant multiplier effect. One-third of the sectors of the national economy are related to the agrarian sector. Agriculture is not only a sphere of food production but also a sphere that provides the entire social share of the reproductive process. The specificity of agriculture also includes the fact that the production process is related to the biological characteristics of plants and animals, which predetermines the discrepancy between the production period and the working period. The working period is the time during which labor is exerted on the product, and the production period is the time from the beginning to the end of the production of a given product (from sowing to harvesting). Due to biological and climatic features, the duration of the growing season for different crops is different. For example, we receive grain from winter crops 9-10 months after sowing, therefore, during the winter period, almost no work is carried out on the care of winter crops. This determines the discrepancy between the production period and the working period, ensuring the seasonality of production, the dependence of the production cycle on the biological characteristics of plants, and the seasons of the year [1-2].

There is a specificity in the reproductive process. In agriculture, products produced in industry are used directly in the reproductive process. According to available estimates, up to 20% of the gross output of the industry is included in the subsequent reproductive cycle as a means of production (seeds, feeds, animal offspring). Agriculture is always a risk zone, because of what the year will be like according to climatic conditions, science makes predictions using air monitoring, and whether there will be an epidemic among animals or not, is generally difficult to predict [3-4].

2 State and Problems of Effective Use of the Production Potential of the Agricultural Sector

Technologies have a contradictory role, both in facilitating unprecedented population growth and in providing a potential solution to emerging problems. Global factors, such as climate change, water availability, labor force, and consumer demand, are challenging the agricultural status quo. Other factors are determined primarily by the appropriate local basic conditions for the individual farmer and their adaptability to technology and change. Despite the problems, there remains an urgent need to provide more and more people with nearly equal amounts of arable land in a short time. The main challenges, which are geographically and technologically interconnected, must be overcome through future-oriented agriculture and technological progress [5]. Information technologies and the digitalization of agriculture have significantly changed the approaches to transformations in traditional sectors and are influencing the structure of consumption. There are new methods in analysis, forecasting, and management decision-making [4].

The long-term goal for the development of the food segment is to ensure national food security and realize the export food potential of the principles of sustainability and innovation. Due to limited resources (immovable nature of land resources as a production factor, regional climatic conditions, increase in extreme weather events) a conflict of goals arises among farmers, when productivity increases, this can lead to soil erosion, water pollution due to the application of fertilizers, plant protection products or emissions of pollutants emitted into the atmosphere. The potential of digitalization lies precisely in the possibility of effective development of production processes, organization, and management. This result is achieved based on innovative technologies through highly specialized and targeted application of appropriate individual resources for production growth [6]. Due to its ability to be applied in many ways, digital transformation provides an opportunity for sustainable development together with increasing productivity in the production process. This argument is valid not only for the production process but also for further processing, as by acquiring and processing data it becomes possible to obtain valuable up-to-date information in the production process and use it for appropriate optimization of the same [6]. As agriculture faces the challenge of supplying the growing global population in economically and environmentally sustainable ways, innovations in analytics and technology platforms play an increasingly important role in supporting decision-making in the field of crop production.

The main task of farmers, farms, scientists, and recently IT specialists is to increase yields while reducing resource use. This trend is provoked by the need to reduce the negative impact of agricultural activities on the environment [7].

Digitalization in agriculture can provide solutions to many of the challenges it faces only if it is applied with foresight and adaptability. Based on Internet of Things (IoT) technologies and the construction of cyber-physical systems. Smart machines must “see” their surroundings and interact via the Internet network with each other, with logistics systems, with suppliers of raw materials, components, and consumers of products. The result is self-optimization, self-configuration, self-diagnosis, the flexibility of industrial production, and product customization. The main obstacle to improving the efficiency of smart production is related to the insufficient digitalization of consumers and society as a whole [8]. But even the very concept of “digital agriculture” is interpreted differently by experts. For some, digitalization in this area is limited to precision farming technologies, for others it is the process of creating large-scale interactive databases that allow making rational decisions in managing agriculture as a sector of the country's economy, for others it is the ability to collect operational data on the course of the production process in agricultural enterprises, etc.. The main hypothesis of the general model of digital agricultural production is that the structure of digitalization processes in agricultural production should be tied to the structure of the main production factors (economic resources) and products. Economic resources can be divided into natural, labor, financial, intellectual, and information resources. As shown in [9], the effectiveness of all economic activity depends on the interaction of these factors, but depending on the external conditions of management and the level of development of technologies, the value of each of the factors may change. In general, agricultural products are plant and animal products, which in turn become raw materials for the food industry to obtain food. As follows from the accepted definition of the digital economy, today the main factor in any type of activity that largely determines the increase in efficiency is information [10-11].

Information that is necessary for modern digital agriculture includes:

- a digital form, since digital information technologies provide the most efficient methods of storing, distributing and processing data;
- represents an information model of all other production factors and products and therefore must be in the form of big data;
- in combination with real material and natural objects, such as a field, machine, warehouse, farm, road, etc., must form smart fields, machines, warehouses, farms, roads, etc.

Digital models of each resource must have a hierarchical structure and cover all levels of management from specific industries to the decision-making system of the country's political leadership.

The common characteristic of digital information resources that describe various factors of agricultural production is, for example, the natural resources of agricultural production include agricultural land, climatic, water, and many other objects that are studied by natural sciences such as physics, biology, geography, chemistry, etc. Their digitization is a difficult and controversial process. People are used to taking nature for granted. The negative impact of humanity on natural resources continues and intensifies. At the 35th session of the International Geological Congress (2016, Cape Town, South Africa), evidence was presented for the beginning of the Anthropocene, a new geological era in which the impact of human economic activity on nature becomes comparable to the biogeochemical potential of the Earth.

Digitalization of natural resources is the introduction of technologies capable of measuring in real-time physical, chemical, biological, and any other parameters of natural processes that characterize the production of agricultural products, and using these data to optimize the ways of human impact on nature [12]. The unification of data obtained in different spatial, temporal, and production areas of agriculture will make it possible to build digital models of natural resources for individual farms, regions, and the country as a whole. This approach to creating digital models can be called decentralized. It differs from the centralized one when information bases are formed at the global level using space or other large-scale technologies. The bottom-up approach to digitalization makes it possible to build truly interactive, intelligent technologies based on big data. All technologies that are needed at this level are called sensorics [13-14]. The labor resource is characterized by the number of employees, their qualifications, wages, and many other parameters.

There are already and are becoming more and more accessible technologies that can replace a person in performing many tasks that are characteristic of agriculture. Information technologies make the arena of human activity, not fields and farms, but digital offices. Along with acquiring competencies in the field of basic principles of biotechnology, cytology, and genetics, problems of nutrition and food safety technologies, and other natural sciences, an agricultural worker needs skills to create new software and hardware products and end-to-end information technologies, the introduction of which leads to a fundamental change in activity models. As a result, the field of application of knowledge of a modern specialist in the field of agricultural production is increasingly becoming not agricultural land, but an information infrastructure that at any moment reflects the state of arable land, plants, and animals, capable of collecting, storing and processing huge amounts of information and developing rational recommendations for management and the course of the production process. From this perspective, the agricultural sector becomes indistinguishable from other high-tech sectors of the economy [15-16]. The efficiency of agricultural production will increase due to informatization, and this will lead to a decrease in the necessary labor resources that are needed for this labor market.

Digital agriculture requires the use of deeper and more effective technologies. Technological processes in agriculture have significant differences from industrial ones, they are associated with biological objects: plants, animals, soil, ecological environment. This feature predetermines qualitatively different requirements for management - these objects have the ability to self-organize and self-develop. A particular difficulty is obtaining information about the behavior of biological objects and interpreting it through technical-informational and analytical means for analysis and subsequent decision-making by a person. Automated control systems (ACS) built from biosensors are complex and expensive. However, this systematic approach to solving a given problem proves that the effectiveness of the whole united in a system is higher than the sum of the effectiveness of each element separately. The use of video surveillance, and technical and computer vision in the management of agro-technological processes can become an effective direction for improving the ACS of processes in agricultural production [17-18]. The emphasis in agriculture will be on optimizing processes.

During the transition from one scientific and technological revolution to another, the means and objects of labor are being improved, and the organization of production is being improved, which leads in the agricultural sectors to an increase in crop yields, animal productivity, an increase in labor productivity, etc. significant economic and financial results [19-20]. Forecasts for the future are reduced to the digitalization of agriculture, which will allow to satisfy the needs of the population for agricultural products, by changing the connections of agriculture with the introduction of “smart” technologies, which will ultimately shape the development of precision agriculture, consisting of precision crop production [21-23] and precision animal husbandry. Some of the applications of these “smart” agricultural technologies are:

- Precision agriculture - navigation systems, electronic remote sensing (ERS) and geographic information systems (GIS), differentiated fertilization;
- Agricultural robotics - unmanned aerial vehicles - for monitoring certain areas, digital sensors;
- Artificial intelligence of things (AIoT) - platforms based on the artificial intelligence of things, AIoT- applications - for controlling and processing data collected from various sensors;
- Big Data - for analyzing information from various sensors in order to prepare preliminary plans and strategies.

Traditionally, Unmanned aerial vehicles (UAVs) are used in agriculture for monitoring agricultural crops, supporting land reclamation, effective herd management, land inventory, controlling the parameters of agro-technological processes, spraying chemicals, guarding facilities, etc. Constant full monitoring of the conditions for carrying out agricultural processes, the dynamics of changes in the state of agricultural lands, and the characteristics of technological processes using technical means for real-time monitoring are the most important prerequisites for the implementation of highly productive and effective agricultural technologies. Information about arable land is used to form real electronic soil and other maps, control the dynamics of changes in the state, characteristics of the bioobject of agricultural production, and operational regulation of ongoing technological processes [24-25].

3 Efficiency Assessment

In the modern world, along with traditional manned aircraft, UAVs are increasingly used for obtaining aerial images [26-27]. UAVs equipped with optical sensors can be used to solve many tasks, the implementation of which with manned aircraft is impractical for a number of economic, technical, and other reasons. UAVs are compact, mobile, and easy to maintain [28-29]. However, they have some disadvantages. Their sensitivity to wind and a small amount of payload are considered to be significant disadvantages. Of essential importance for solving the tasks is the receipt of highly informative images, and their effective processing in order to extract and qualitatively assess the parameters and characteristics of the observed objects.

This article will determine the threshold size of the area for obtaining aerial images, at which the UAV loses its effectiveness compared to traditional aerial equipment, as well as consider the reasons for the decline in economic efficiency. To determine the economic efficiency of using UAVs, it is necessary to calculate the financial costs, which are defined as the sum of all costs for the work performed:

- costs of creating a plan-altitude justification;
- costs of photographic work;
- costs of transport equipment;
- remuneration of employees.

Before calculating the costs, it is necessary to determine the density of the marker distribution. To do this, it is necessary to calculate:

$$L_x = L_y = R \cdot \sqrt{Mpix} \cdot 1000, \quad (1)$$

The second stage is the examination of the where L_x and L_y are the size of the area that is displayed in the snapshot at the resolution R of the image; $Mpix$ – number of megapixels in the image. Also, to determine the density of the markers, it is necessary to know the basis of photographing B_x and the distance between the routes B_y [30]. The size of the longitudinal p_x and transverse overlap p_y is usually set to 60 and 30%, respectively [31]:

$$B_x = \frac{L_x \cdot (100 - p_x)}{100\%}; \quad (2)$$

$$B_y = \frac{L_y \cdot (100 - p_y)}{100\%}. \quad (3)$$

The number of bases n_b between the height markers depends on the accuracy of building the stereo model by height m_Z and the specified relief height h_s.

$$n_b = \sqrt{\frac{4 \cdot h_s^2}{m_Z^2}} - 45 - 1, \quad (4)$$

where $m_Z = \frac{L_x \cdot \sqrt{2}}{2tg\frac{2\beta}{2}} \cdot \frac{0.5}{1000 \cdot \sqrt{Mpix}} \cdot 6$; 2β is the field of view of the lens.

Using equatinons (2), (3) and (4), the density of placement of signs per square kilometer of the shooting area is determined n is calculated as

$$n = \frac{10^6}{n_b \cdot B_x \cdot B_y}. \quad (5)$$

4 Conclusion

Natural wildfires, which include fires in forests, steppes, peat bogs, and other natural sites, are dangerous and dynamic processes that cause great damage to nature and infrastructure and often lead to human casualties, which in turn threatens national security. Very often, we have to fight natural fires by attracting a large number of firefighting forces and means. This raises the task of rational planning and management of these forces and means.

In recent years, in connection with the creation of space systems for monitoring forest fires, as well as the rapid development of technology for using UAVs, it has become possible to assess the parameters of forest fires in real-time, which opens the way to operational control systems with feedback.

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