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THE ROLE OF DIGITAL TECHNOLOGIES IN THE SUSTAINABLE DEVELOPMENT OF PRECISION AGRICULTURE

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Abstract: The article describes modern problems of agriculture, trends in their development and elements of digital agriculture.

Keywords: digital technologies in agriculture, agriculture 4.0, digital agriculture, precision farming, smart agriculture, precision agriculture

Аннотация: В статье описаны современные проблемы сельского хозяйства, тенденции их развития и элементы цифрового сельского хозяйства.

Ключевые слова: цифровое сельское хозяйство, сельское хозяйство 4.0, точное земледелие, умное сельское хозяйство.

The demand of the world's population for food products is also increasing year by year. The global population was 7.8 billion in 2019 and is projected to exceed 9.6 billion by 2050, leading to a significant increase in demand for food. [1]

At the same time, available natural resources, including fresh water and fertile arable land, are also diminishing.

But production is not the only factor that worries us: today's agricultural production is enough to feed the entire world, yet 821 million people around the world suffer from hunger. [2]

In this situation, the development of modernization processes in the agricultural industry has a strong impact on the processes of food production and consumption. In particular, there are more than 570 million small farms in the world [3] and the employment of 28% of the world's workforce in the agri-food sector is proof of this [4].

By defining the concepts of "agricultural modernization" in a "broad" and "narrow" sense, we are ready to amicably perceive any form of discussion and criticism. Therefore, the sustainable development of agriculture through modernization requires scientists to constantly strive to connect the achievements in national goals and tasks with the territorial and regional diversity of the region. It is necessary to look for new methods and forms for concrete implementation in practice. [5]

Like the industrial revolution, the development of agriculture can be divided into the following 4 main stages of development:

After the development of agriculture passed from the use of animal labor to the means of production, the need for mechanization of production arose. It started to require a lot of labor and time in the process of growing products on large arable fields.

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Due to the fact that the human factor in the work of steam engines and motor tractors was still large, the introduction of the farm system made it possible to systematize agricultural production.

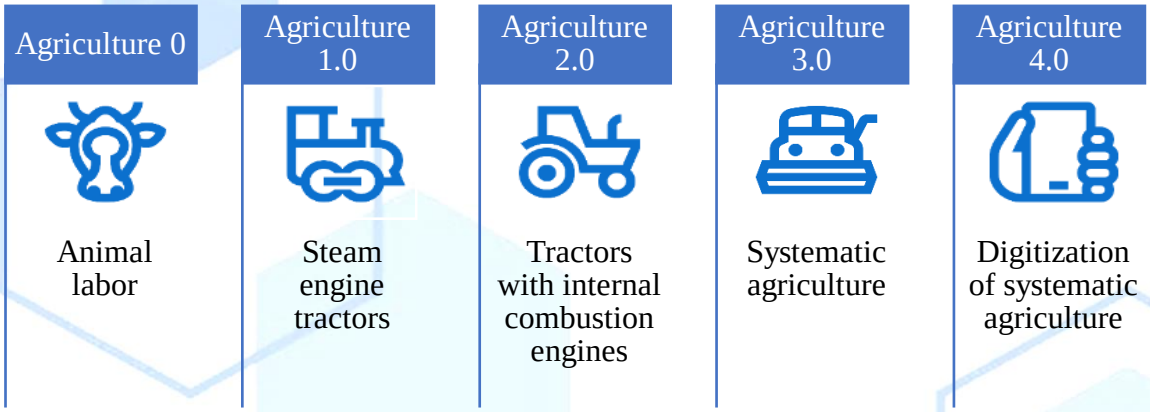

Figure 1. Periods of development of agricultural production [6]

Agriculture has always played an important role in human life. New technologies affecting farming models have a long history of development.

Let's focus on four stages of changes in agriculture. Agriculture 1.0 is labor intensive and involves the use of animal power. Agriculture 2.0 is related to various agricultural techniques. They also include the use of various chemicals. However, these trends have led to increased productivity and serious environmental damage and waste of large amounts of resources. [7]

Computer technology led to the development of agriculture 3.0 in the 20th century. The use of chemicals has been reduced. The concept of sustainable development of agriculture was introduced. [8]

However, with the rapid development of digital technologies, global problems have arisen that the world faces. [9]

Agriculture 4.0 has emerged to mitigate these global challenges. A number of global problems affect the stability of the agricultural system. At the heart of the need for digitalization of agriculture lies the scarcity of economic resources. One of the main reasons for the introduction of new models of modern agriculture is the growth of the population and the large amount of food waste produced by them. Also, the increase in air temperature and climate change in the globe is increasing the need to introduce digital technologies in agriculture.

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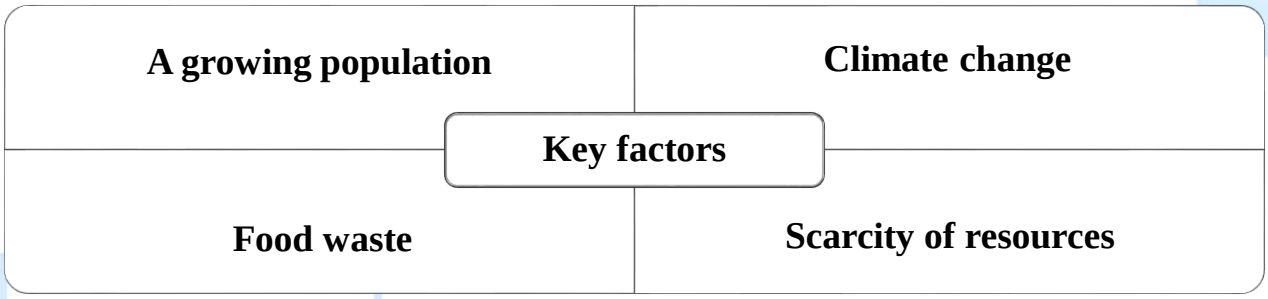

Figure 2. The main factors that require the implementation of Agriculture 4.0 [10]

United Nations World Population Development Prospectus shows that the population will increase by 10 billion by 2050. This leads to an increase in the demand for food. According to the FAO, agriculture must provide 70% more food by 2050. These trends require increased productivity and efficiency. In contrast, 33% to 50% of food produced is wasted.

In general, Agriculture 4.0 aims to change the culture and behavior of all actors involved in the agricultural production chain in agriculture, to increase their productivity and efficiency and support a more sustainable agriculture. It is an information base that helps to implement new technologies and innovative services and make strategic decisions. [11]

Agriculture 4.0 is a set of artificial intelligence products that can make independent decisions in production and eliminate the human factor based on the introduction of digital technologies in agriculture.

According to our conclusions, there is no universally accepted definition of the term agriculture 4.0, and the concept of agricultural development is constantly changing. Also, based on the introduction of digital technologies in agriculture in recent years, agriculture continues to develop steadily.

We can cite the following as examples of the most widely used digital technologies in agriculture (Table 1).

Table 1.

Types of digital technologies used in agriculture [12]

Name of digital technology	Description
Precision farming	A farming management concept based on observing, measuring and responding to inter-field and intra-field variability of crops. Agricultural precision research aims to define a decision support system for whole farm management in order to optimize input income while conserving resources.
Artificial intelligence	The ability of a digital computer or computer-controlled robot to perform tasks normally associated with intelligent beings AI

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	can be programs that act like humans, work like humans, think like humans, or have a unique intelligent way of processing information and/or behavior. Its applications are endless in many aspects of technology development.
Remote sensing	the science of obtaining information about objects or areas from a distance, usually from aircraft or satellites. Images can be captured using active sensors or passive sensors at different wavelengths of the light spectrum. Passive sensors record light as it reflects off the Earth's surface, while active sensors use their own stimuli to create an image, such as a laser beam. Remote sensing applications in natural resource management (eg, for agricultural land use) are useful for monitoring agricultural production, productivity, and drought.
Blockchain technology	a system in which lists of records known as blocks are linked using cryptography. Each block contains the previous block's cryptographic hash, timestamp, and transaction information. In this distributed database, records (represented by blocks) of all transactions or digital events performed and shared between participating parties are stored.
Internet of Things (IoT)	global network infrastructure, where physical and virtual entities with unique identities are found and are continuously (taking into account security and privacy issues) in a connected information network capable of offering and receiving services that are business elements are combined. processes identified in the environment in which they are activated. In the context of agriculture, any element involved in the value chain of plants produces information that can then be processed for various purposes.
Information and communication technologies (ICT)	Different types of technologies that deliver information to users through telecommunications. Technologies include wireless networks, Bluetooth, the Internet, mobile phones, SMS and MMS.
LIDAR method	combining different sensors of different frequencies and types of light to measure distances, which can then be used to create 3D images. A laser beam is used to create light that is reflected off a surface and then captured by a sensor. Types of light used include ultraviolet, visible, and near infrared. It is a common technology in autonomous vehicles and equipment.

In our opinion, it is a difficult task to introduce the elements of a relatively new concept in agriculture. There are no final conclusions [13] on the scientific debate on the principles of Agriculture 4.0, so there is no unified opinion about its theory among the participants [14] in the region.

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The figure below presents a proposed classification of the elements that form the basis of agriculture 4.0. This systematized proposal is not a precise formulation, but has a didactic and concrete character that facilitates the understanding of its main elements.

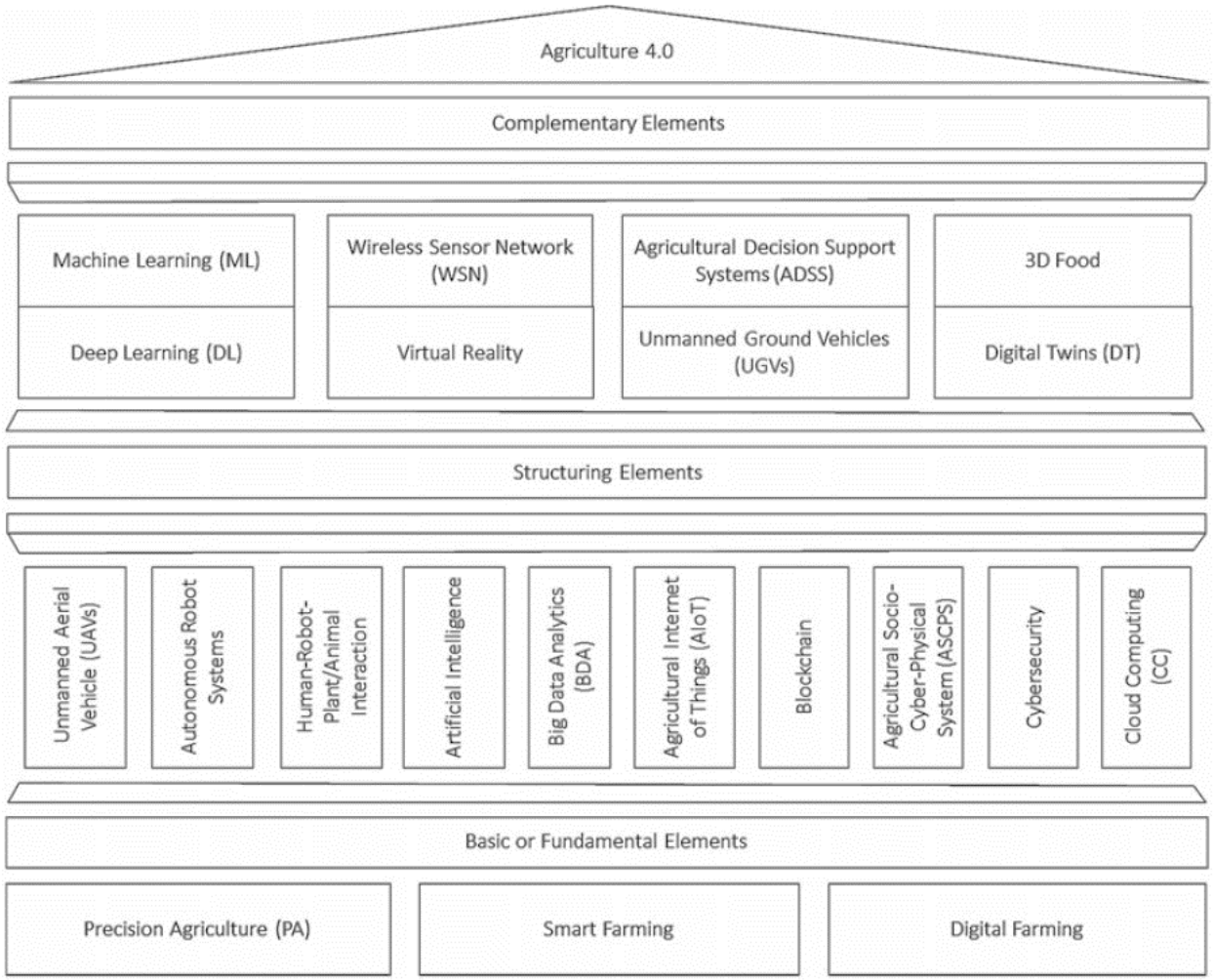

Figure 3. Organizational structure of agriculture 4.0 [15]

Fundamental or key elements: As a basis, one can find the fundamental concepts that guide the development of Agriculture 4.0, which this concept relies on (precision agriculture, smart farming and digital farming) and without which it would not exist. not In addition, these elements are the main pillars of the creation of the theory of agriculture 4.0.

Structural elements: At the top of the organizational structure of Agriculture 4.0 are the basic technologies that can revolutionize and influence the way goods are produced, processed, sold and consumed. The use of these technologies can guarantee the future of global agriculture (ie, in the detection of crop diseases, efficient control of machines, cost reduction, better knowledge of cultivated areas, effective use of toxic substances and pesticides). From these structural elements, it becomes easier to achieve

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higher productivity with improved product quality, efficiency in agricultural management and reduced environmental impact.

Complementary elements: These are elements that expand the possibilities of agricultural action. However, they address specific agricultural issues that require a certain degree of maturity with the structural elements of Agriculture 4.0. Only in this way can a significant effect be achieved with additional elements. In addition, as the use of technologies of this element begins worldwide, it will be important to make them relevant and robust so that more countries seek to introduce them in the construction of a new global agricultural scenario.

Roof: The roof represents Agriculture 4.0. However, the whole structure of the "Agriculture 4.0 Organizational Structure" will be strong if the foundation and walls are solid and well built. Therefore, every element of the house is very important, but more important is how the elements strengthen each other. Thus, the house is durable only if the roof, pillars and foundation are strong.

The elements of the organizational structure of Agriculture 4.0 are equally important in the development of agriculture. Many other elements are not listed or appear every day, and they support agriculture 4.0 in many applications. But it is unclear which of the Agriculture 4.0 technologies will pass the early stages and be widely adopted. [16]

In our opinion, the spread of new ideas and technologies is not always fast; in general, transitions in large-scale agriculture can last more than a decade or even several decades.

Nevertheless, as the scale of countries willing to adopt and implement Agriculture 4.0 technologies increases, it will be possible to achieve higher agricultural productivity and profitability without burdening the environment. At the same time, it contributes to the achievement of the United Nations Sustainable Development Goals, while at the same time accelerating strategies aimed at reducing global poverty, environmental damage and social inequality.

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