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# THE MECHANISM OF DIGITAL TRANSFORMATION OF AGRICULTURE

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## **Abstract**

*The article is devoted to the study of the construction of the mechanism of digital transformation of agriculture when building a management system for agro-industrial clusters. The new realities of socioeconomic relations at the international level and the level of individual states require involvement in digitalization trends. That makes it necessary to study the mechanism of digital transformation of the branches of the national economy, including agriculture. The use of new IT technologies contributes to the formation of competitive advantages and directions for the development of the industry. On the other hand, it acts as an incentive to activate and increase the efficiency of the management system by stimulating the introduction of achievements and trends in modern science and technology, which is especially important in the digitalization and digital transformation of agriculture. Accumulation, systematization, and generalization of traditional-historical and modern IT technologies and management system techniques is an element of integration and activation of network, cluster, and other innovative mechanisms in the modernization of the management system in the agro-industrial complex. The development of the agriculture digital transformation will allow to specify of the tools and methods of updating and building integrated management systems of system-forming innovative agro-clusters will allow to generalize of the theoretical and methodological foundations, and develop recommendations for the formation of a management model of system-forming innovative agro-clusters using the concept of "triple helix" and modern digital technologies in the field of agro-industrial complex of Russia.*

**Keywords:** *digital transformation, management systems, agro-clusters, agro-industrial complex, triple helix model, digitalization, agriculture, artificial intelligence.*

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## 1. INTRODUCTION

The change in the general paradigm of the capitalist to the post-capitalist social way of life and the transition from the industrial to the post-industrial mode of production led to the modernization of coordination and the construction of the structure (model) of communication, which in turn led to an evolutionary transformation of the management system. Analysis of the evolution of world relations makes it possible to generalize, systematize, and conditionally single out three control systems for various spheres of society:

1. Hierarchical,
2. Market,
3. Integrated network.

As practice shows, the formation of a three-tier management system took place, on the one hand, under the influence of the information needs of society, the state, the economy, and science, and on the other hand, the need to expand the coordination system of network connections and increase the efficiency and mobility of the management system itself in the course of using innovative and digital collection tools, processing, storage, and use of information.

The evolution of management systems is characterized by a gradual transition from a rigid model of connections (hierarchical) to a flexible one - integrated (network), which assumes the most flexible model. In doing so, it is necessary to observe certain restrictions. In the process of evolutionary development, the number of subjects of management expands through a gradual transition from a sole to a chaotic management system. That leads to the absence of partnerships between the main participants and the emergence of vertical ties, where the subjects of management are not one governing center but a "symbiosis" of the major participants. Such a new management system contributes to the emergence and functioning of agro-clusters - as backbone and innovative management systems. We agree with the opinion of N. Smorodinskaya, who notes that "the systems headed by the control center cannot cope with the increasing flows of information and are increasingly being replaced by network systems built on horizontal (non-hierarchical) connections and the principle of collaboration" (Smorodinskaya, 2011, p. 67). In our opinion, the

use of the principle of collaboration in the process of creating and functioning of agro-industrial clusters (agro-clusters) will make it possible to intensify the interaction, cooperation, and exchange of knowledge, technologies, and other resources between core stakeholders, and coordination in a single space of the control system. Clusters are becoming one of the crucial platforms within this management system since they act as a structuring element in the world economy development.

The instrument for the implementation of the new management system is the concept of the "triple helix" - a collaboration of the state, business, and science, taking into account the factor of digital transformation, digitalization of economic processes, and the intensification of the use of digital technologies and the achievements of scientific and technological progress, which is especially important for agriculture. Historically, the concept of the triple helix originated in the 90s in the field of sociology and biology. This model bases on the spiral of G. Itskovits, who defined it as "an attempt to represent visually the variability and flexibility of interactions ... the model invisibly contains the fourth element - time, around which, changing and developing, all three spirals wind" (Etzkowitz, 2008). The use of the triple helix model in the agro-industrial complex makes it possible to build innovative backbone clusters, the determining factor being the network connections that arise in the control system. According to many authors, "the active development of networks in modern markets is determined by the possibility of saving costs and combining the resources and abilities of participants, which allows them to jointly create additional value and receive mutual benefits from network interaction, achieving a common goal" (Oborin & Sheresheva, 2017, p. 27).

Since the agro-industrial complex of Russia can provide the population with the necessary amount of food, trends and the general vector of its development become part of state policy and priority national projects implemented at the macro, meso, and micro levels. In the current conditions, the construction of an effective management system for agro-industrial clusters is impossible without the active use of digital technologies and innovations, which is "due, on the one hand, to the activation of the general

strategy of digitalization of the economy as a whole, as well as the need to introduce scientific achievements and technological progress into the management system of the agro-industrial complex of Russia, to increase its efficiency and competitiveness of the industry" (Shogentsukova & Shogentsukov, 2020).

The inhibition of the efficiency of agricultural development is due to several factors: the non-systemic nature of the industry management system both at the level of its participants within the agro-clusters and at the state level; a low level of understanding of the need to rank and justify a phased transition to the digital transformation of agriculture and its gradual transformation into an ecosystem, as well as the lack of interconnection between the processes of adoption at regional and federal levels of state power, state programs in the field of agricultural development, fragmentation of methodological and information support, unsystematic management in the agro-industrial complex, causes the need to study the modernization of the management system of agro-industrial clusters (agro-clusters) in the context of digitalization.

## 2. MATERIALS AND METHODS

The Russian Federation possesses vast territories and a complex management structure for the agro-industrial complex, due to the diversity of the production process of agricultural products and schemes of interaction between participants in agricultural production, from the preparatory processes, and production to the promotion (sale, marketing).

In the course of studying the evolution and modernization of the agro-cluster management system, the methodological basis is a set of scientific, interdisciplinary approaches, including a systematic approach, including general scientific and specific methods: systematization and generalization, comparison, historical and structural-system analysis, used in various combinations to solve the set goals and tasks, ensuring the formulated conclusions and recommendations.

The study of the modernization and development of the management system in the field of agriculture contributes to the systematization and building of a system for coordinating the directions

of interaction between the core participants in all processes of the agro-industrial complex within a single space, for example, a cluster - as a system-forming and self-developing system of management of the country's agro-industrial complex in the context of digital transformation and digitalization of all processes Agro-industrial complex.

The systematization of the development of economic and social relations in the world conditionally allows us to distinguish the three management systems presented in Fig. 1.

The evolutionary development of the management system in the field of the agro-industrial complex makes it possible to single out several points:

1. *Hierarchical management system - assuming an administrative-centralized management system with a rigid model of connections.* The main subjects of management are the state and the company. The management system is built within a rigid hierarchy and with a vertical chain of command and coordination in decision-making. This system is a classic management system for both the economy and the state as a whole. The most striking example is the Russian economy of the Soviet Union period, characterized by a rigid unification of all processes and the management system itself. We agree with Polbitsyn's opinion. He notes that "rural entrepreneurs rely on their resources and capabilities, and also government and local government bodies" (Polbitsyn, 2019, p. 305). The main participants in agricultural production are quite skeptical about digitalization and the introduction of innovations since individual enterprises do not have sufficient resources for innovative activities development and cannot act as a "growth point" (Shogentsukova & Shogentsukov, 2020).

The transition from the classical to the market and then to the integrated management system is closely related to the change of economic systems: command-administrative to market industrial, which requires the active use of digital, including online, technologies for coordinating the management system. In

modern economic relations, the presence of price and other market benchmarks becomes insufficient; coordination between producers and the consumer becomes necessary not only through traditional communication methods but also through network

communications using Internet technology. By formatting databases, large Internet companies create an entirely new environment for economic relations, including agriculture.

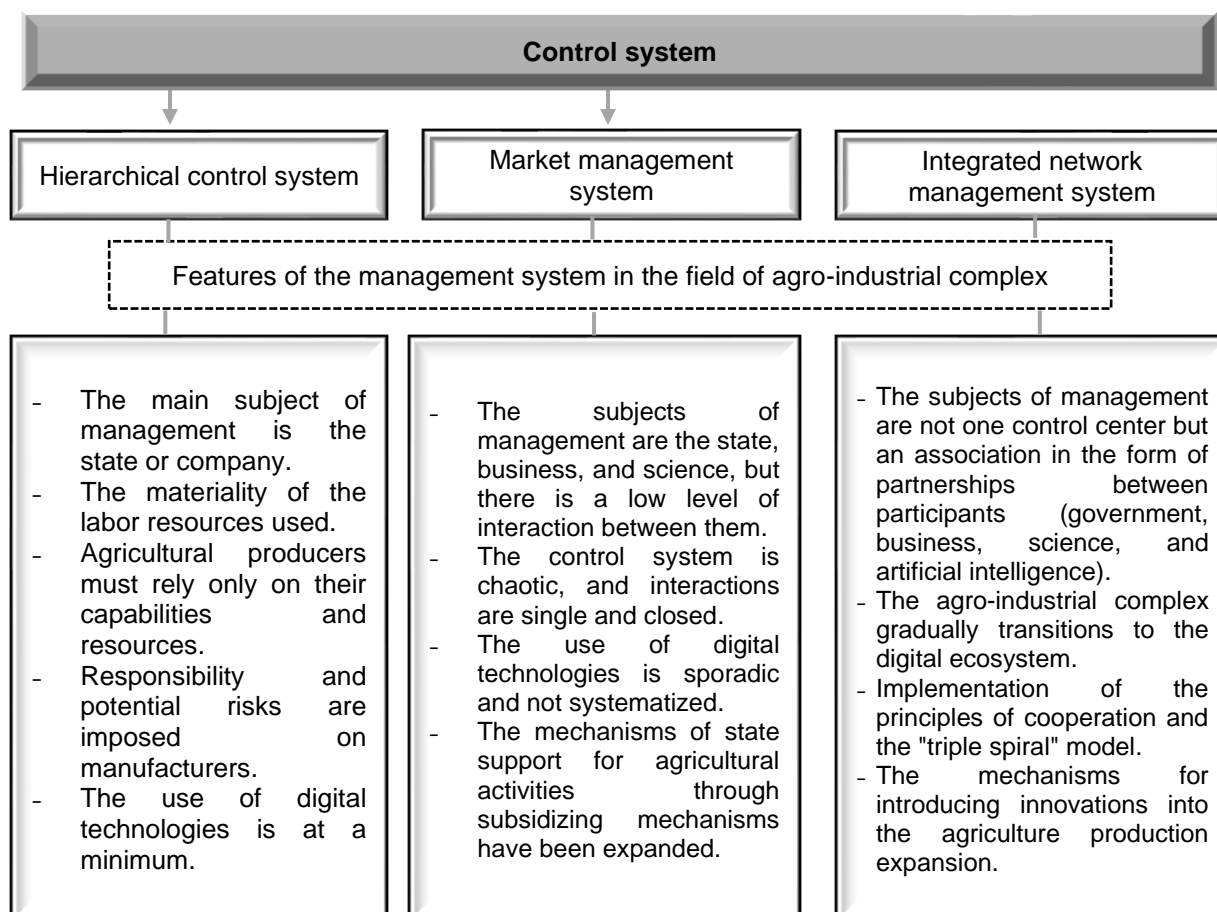


Figure 1. Evolutionary development of the management system in the field of the agro-industrial complex

2. *Market management system - based on the implementation of traditional laws of the market (market relations).* Compared with the hierarchical management system, this system is more flexible, but at the same time, certain restrictions remain. The subjects of the management system are expanding: representatives of business, government, and science. Market relations are expanding agricultural management tools, mechanisms for introducing innovations and digital technologies, and "partial automation" of managing production processes in the agro-industrial complex (AIC). For example, digitalized agricultural equipment, sensors, unmanned aerial vehicles, and other digital

elements are emerging. The possibility of detailed monitoring and control over yield indicators and other parameters affecting cost reduction and risk reduction confirmed the effectiveness of digital and modern technologies. Oborin M.S. notes that "in the transition to smart agriculture, humans will play a secondary role in tracking the current state of the natural environment. This function will be taken over by various sensors that will analyze the state of the components of the natural environment (air, soil, water), as well as automatically control lighting, irrigation, and fertilization" (Oborin M., 2019, p. 224).

The market form of management does not cope with the large flow of information

generated and transmitted through global economic networks and coordinating platforms, which requires the application of the principle of 'collaboration' teaching the activation of interactions and coordination of ties between cooperation participants who exchange knowledge and assets, unite when making decisions. (Alikaeva, Ksanayeva, & Prigoda, 2020)

3. *Integrated-network control system - emerging and applied in the conditions of building vertical links, the most flexible control system.* In our opinion, such a management system allows the creation of backbone agro-clusters built on the principle of 'collaboration', activating the processes of cooperation and knowledge exchange, technologies, and other resources between the main participants through cooperation and coordination.

In the field of the agro-industrial complex, a gradual transition to a digital ecosystem of agricultural management is being activated. That implies the creation of a single digital space for most participants in the production and the products (works, services) promotion. This management system involves expanding the areas of application of modern digital technologies and innovations, which in turn make it possible to develop or strengthen the existing competitive advantages of the industry. In the Russian Federation, the digital transformation of agriculture is a geopolitical and significant factor in the development of the agro-industrial complex, which is part of the spheres of national interests since the development of agriculture is a factor in ensuring the country's food security. Figure 2 schematically illustrates the mechanism of digital transformation of agriculture.

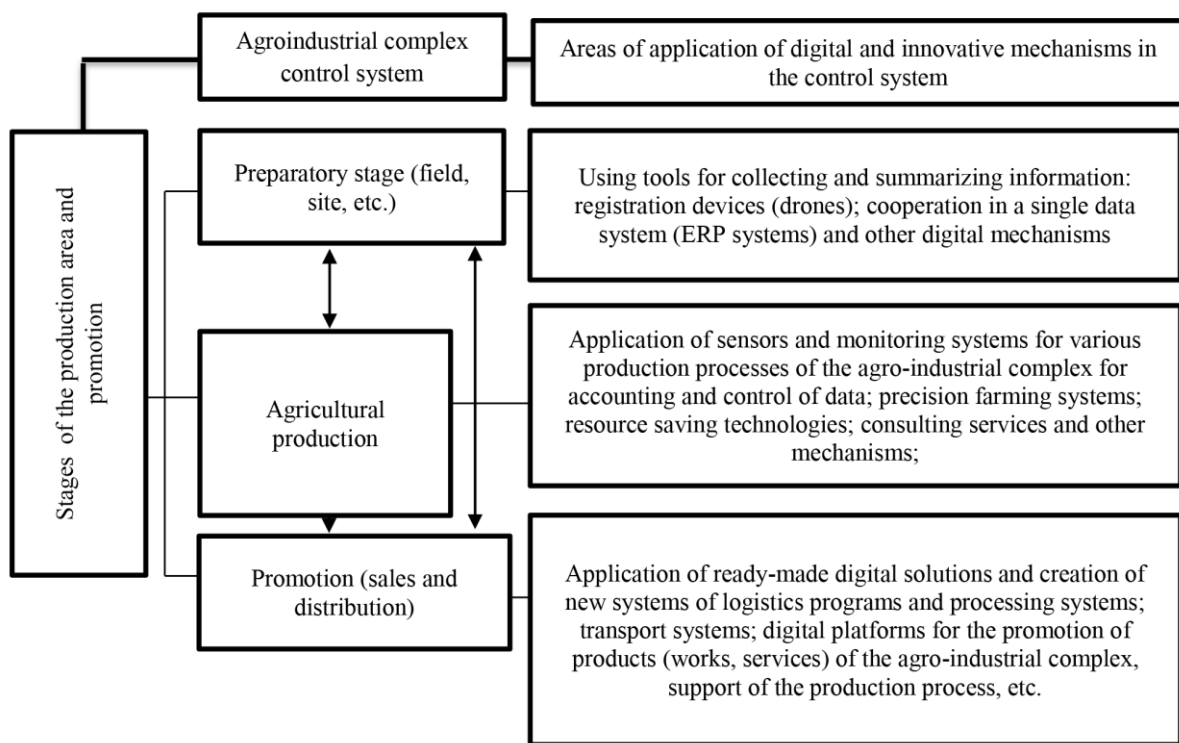


Figure 2. Mechanism of digital transformation of agriculture

Source (Shogentsukova & Shogentsukov, 2020)

The use of this mechanism for the digital transformation of agriculture should assume the presence of universal systems for managing the production process and the sale of products (works, services) of the agro-industrial complex, capable of covering a large amount of input data and their systematization, accumulation, and

analysis. The control system should allow the use of multivariate tools, be mobile, and be capable of adapting to the rapidly changing conditions of the functioning of agricultural entities. Also, a significant factor is the degree of coverage of all stages (stages) of the production process and the promotion of products (works, services).

Practical experience shows that the basic model of digital transformation of agriculture should be modified considering the complex problems of the agro-industrial complex. The solution to this problem is possible by weaving digital technologies into the management system of the country's agro-industrial complex, which can facilitate or create effective feedback tools between the major participants in the production cycle and marketing of agricultural products (works, services). In these conditions, the use of digital and innovative mechanisms allows the Control System to solve pinpoint problems of the agro-industrial complex. However, to increase the scale of the implementation of the digitalization process in agriculture, it is necessary to create conditions for the functioning of the agro-industrial complex management ecosystem (Shogentsukova & Shogentsukov, 2020). The need to create a single platform for approvals and expanding platforms for communication between participants in agricultural production and marketing creates conditions for a gradual transition and consideration of the agro-industrial complex as an ecosystem that requires the activation of the introduction of digital technologies and innovations without selectivity but with the maximum coverage of all processes. The degree of implementation of digital and modern technologies in the management system significantly impacts improving the efficiency and overall competitiveness of the industry. The ecosystem approach in agriculture, and the use of clustering, are tools of the general management system of the agro-industrial complex.

In our opinion, when forming the conceptual foundations for the modernization of agriculture, it is necessary to consider the agro-industrial complex (AIC) as an ecosystem, a system that unites into a single space not only participants in agricultural production and sales but also other structures: government agencies, business representatives and scientific community (universities, research centers). At the same time, the agro-industrial complex ecosystem is a self-developing system of functioning of various participants in a single environment (Shogentsukova & Shogentsukov, 2020). The application of the ecosystem approach in the

Russian economy, in particular in the agro-industrial complex, is, in our opinion, relevant, in the conditions of non-systematic and situational territorial and subject specialization, inconsistency, and non-systematic decisions at various levels of management.

The complexity of building a management system in Russia is the need to reduce the degree of 'complete' unification and gradual transition from total government in various industries, when the main subject of government is the state authorities, to a modified one that involves an expansion of government subjects. At the same time, an effective and efficient management model construction presupposes the formation of a system of not only 'partnership' relations but also the intensification of the participation of other government entities other than the state. Cooperation and interaction of the main institutional sectors will allow not only to accumulate and combine the opportunities and resources available to them but also to expand the mechanisms for the use of new modern technologies and innovations, including the digital transformation of the industry (agriculture). As noted by some authors (N.E. Bondarenko and T.P. Maksimova), "the intersection of three sectors (government, business, and science) is becoming a new mechanism for achieving consensus and a universal institutional matrix for innovative growth" (Bondarenko & Maksimova, 2016, p. 16), within this, each of the participants is a separate subject of the management system.

In our opinion, only in the context of the intensification of the use of 'scientific knowledge' in production activities in the agro-industrial complex, it is possible to apply the concept of a triple helix and transform the management system of agro-clusters from a traditional to a backbone and innovation system. At the same time, universities and research centers are crucial sources of scientific knowledge. Increasing the level of interaction between research centers, universities, and the state can help expand the university's capabilities in the implementation of scientific, intellectual, and other achievements obtained during research and design, and innovation activities. An innovative mechanism that arises because of cooperation, and not in the

form of individual demand or supply, significantly increases the efficiency of various categories of projects. The construction of the model (matrix) of the 'triple helix' is based on the concept of cooperation, not on the influence and control between the participants in this spiral. It is a cooperation that becomes the starting point for the development.

The widespread use of the collaboration mechanism contributes to the emergence and formation of a cluster-network management system in which various participants are united into a cluster, which occurs by combining resources, ideas, and general coordination of tactical and strategic development plans. The basis of the 'triple helix' matrix is the "evolutionary concept of technology development" that affects the processes of economic growth and the network connections used in the system. In parallel with these network connections use, the economic systems and the model of interaction between participants in the agro-industrial complex are changing.

According to several authors, "the main element of novelty in the innovation model of the triple helix is the strengthening of the role of the university" (Shogentsukova & Shogentsukov, 2020). In previous models, the emphasis was on the state or business. The most optimal option is considered a model in which the interaction of all three participants in the spiral is approximately equal in development. At the same time, there is a change in universities, a transition from a purely educational and scientific institution to an "entrepreneurial" one, i.e., innovative. Applying the "triple helix" model can ensure the country's agro-industrial complex (AIC) sustainability development. It presupposes integration, selection of technologies, and resources used in agriculture. State and regional authorities must ensure a level playing field, reaching a compromise of interests of all participants in the model: business, government, and universities. The intersection of interactions between the state and business is based on formal and informal ties. An increased degree of communication between the state and science is developing between scientific and educational organizations under the jurisdiction of the Ministry of Education and

Science of the Russian Federation. But at the same time, there is no general policy in innovative development.

### 3. RESULTS AND DISCUSSION

For the efficiency of the agro-cluster management system, it is necessary to take into account the trends of scientific and technological development, including the intensification of the use of modern and digital technologies, i.e. science-intensive technologies requiring the involvement and activation of the participation of representatives of the scientific community in the production of agricultural products (works, services). The use of high-tech technologies determines the innovativeness of the creation and functioning of clusters. The USA, Denmark, Finland, and China implemented that approach fully. The use of science-intensive technologies as the basis for the construction and management of clusters requires resources that developed and diversified economies can afford. On the other hand, it becomes possible to create or enhance competitive advantages and investment attractiveness of both the main participants and the industry as a whole. Building a rational management system for backbone innovative agro-clusters can become a multiplier effect on the development of agriculture both in individual regions and in the country.

Cluster management in Russia predominantly involves the active participation of the state, but at the same time, to increase the efficiency of the cluster, it becomes necessary to expand the participants in this process. The presence of representatives of government, business, and the scientific community allows for balancing control over the use of resources while respecting the interests of all participants. The use of the "triple helix" model in the formation of backbone innovation clusters implies "triple coordination determines the performance by the participants of previously uncharacteristic functions, the traditional function of business is the introduction of innovations, the university is in the production of knowledge and technology, the state is the establishment and regulation of the relations of the participants" (Kozlov, 2016).

The application of the triple helix concept modifies the role of the main subjects of governance: the state becomes a public entrepreneur or “venture capitalist” willing to invest in startups; research centers and universities are stepping up their participation in entrepreneurial activity; the private sector, i.e., business is involved in educational and research activities, which in turn can significantly expand the mechanisms for

increasing the efficiency of the industry development both at the macro, meso, and micro levels. A significant factor in agro-industrial clusters in the Russian Federation is the need to consider territorial differentiation, i.e., the allocation of areas of advanced development for the production and processing of agricultural products.

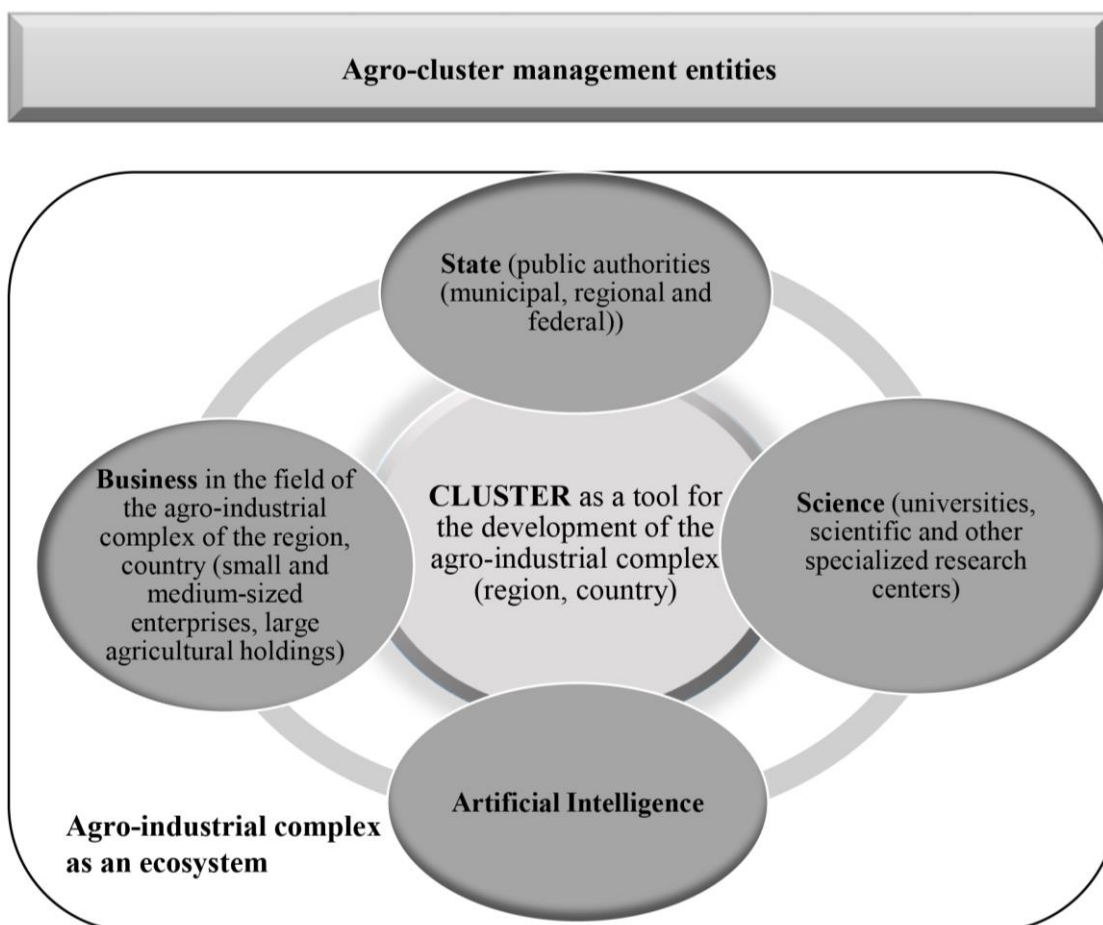


Figure 3. *Subjects of the cluster model of the agro-cluster management system (region, country)*

Source: (Oborin, Alikaeva, Shogentsukova, & Shogentsukov, 2022)

Clusters act as a tool for the development of the agro-industrial complex, uniting not only various forms of management, ranging from farmers and small farms to medium and large agricultural holdings but also creating a single space where the subjects are representatives of various institutional spheres (see Fig. 3).

In addition to those highlighted in Fig. 3. participants in the "triple helix" model, a significant element is artificial intelligence. The implementation of the cluster approach in the agro-industrial complex at the level of individual constituent entities of the Russian Federation can

become a catalyst for the development of the region, as well as a multiplier for the application of the obtained positive trends not only in agriculture, but also in related sectors of the national economy: transport, light and food industries, mechanical engineering, and the chemical industry.

In the modernization of agriculture, a significant element is the intensification of the use of artificial intelligence as a technology for improving the management system of agro-clusters. At the same time, this technology is used in various directions and stages of production activity: from

identification of agricultural raw materials to production and processing, ensuring the effectiveness of promoting agricultural products. With the help of artificial intelligence in the agro-industrial complex, it becomes possible to intensify the processes of digital transformation of agriculture, which is especially important in the context of the need to reduce the dependence of the production process on the climatic, seasonal, and other sectoral features of agriculture. Climate forecasting, simulation, and the creation of special conditions necessary to achieve the efficiency of production technology and the promotion of agricultural products are possible with the use of artificial intelligence technologies, which in turn can become a competitive advantage for the industry as a whole. The result of the use of these technologies, on the one hand, is an increase in labor productivity, but on the other hand, there is a demand for highly productive personnel (there is an expansion of human capabilities in the workplace; the emergence of new professions), which universities and research centers can provide the market with. These difficulties can be solved at the level of functioning of agro-clusters and cooperation between the main participants.

Integration and global processes, as well as the intensification of digitalization of the economy,

including agriculture, require mobility from the management system. Lagging behind advanced technologies is becoming a threat not only for individual countries, businesses, and the scientific community but for all systems of socioeconomic and legal relations and the world economy.

The objects of management of agro-clusters (see Fig. 4) are the resources necessary for agricultural production activities, which include three stages: preparatory, production (processing), transportation, and promotion of agricultural products. When building a management system in the field of agriculture, it is necessary to take into account the following factors that are specific features of the industry: the crucial means of production is land, i.e., the need for a territorial production basis; territorial dispersion of production, remoteness of subdivisions from the control center; significant dependence on natural and climatic conditions and with other related sectors of the national economy, etc. Reducing dependence on these factors is one of the main goals of agricultural modernization, which can be achieved using specialized production mechanisms, modern new approaches, and other innovations, for example, the creation of a special environment - a greenhouse.

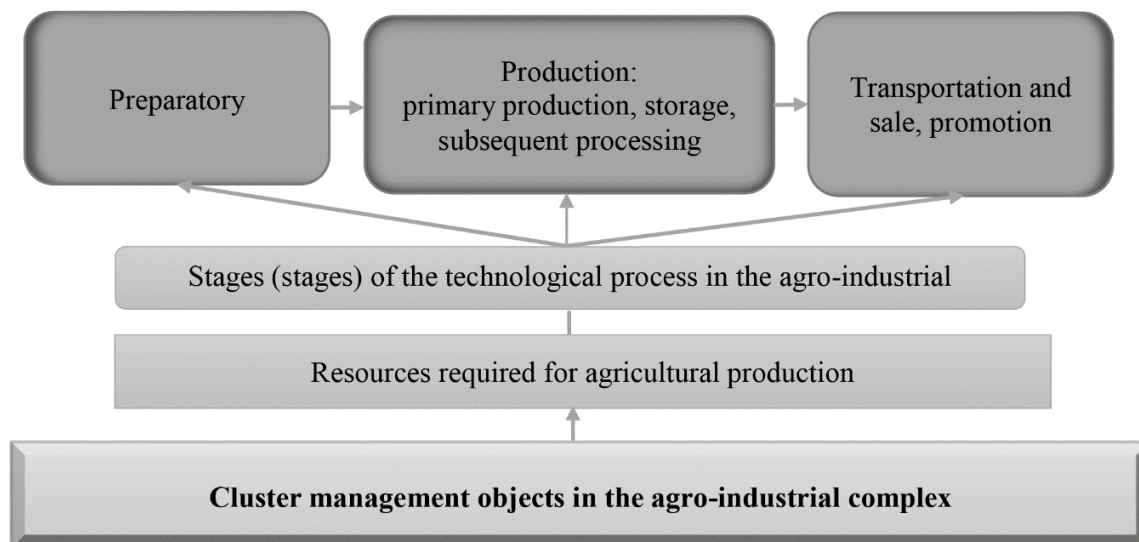


Figure 4. Objects of the cluster model of the agro-cluster management system (region, country)  
Source: (Oborin, Alikaeva, Shogentsukova, & Shogentsukov, 2022)

A significant factor in the development of the agro-industrial complex is its transformation into an ecosystem that involves not only the activation of

the use of modern technologies and the digital transformation of agriculture but also expanding other mechanisms for the development of the

management system. The creation and application of agro-industrial clusters (agro-clusters) as backbone innovative management tools in the field of agriculture, in our opinion, should be considered as an innovation project aimed at developing the industry not only at the country level but also at the level of individual subjects (regions) of the Russian Federation. The functioning of the agro-cluster provides for the activation of the achievements of scientific and technological revolution, and the formation of a specialized infrastructure that ensures the coordination and adoption of various categories of organizational and managerial decisions by the main subjects of the management system. The intensification of the application of science "influenced the creation and functioning of an integrated information system for enterprise management, providing managers with the data necessary for planning, monitoring, evaluating business operations, making management decisions" (Shidov, Gedgafova, Kazieva, Sizhazheva, & Shogentsukova, 2019, p. 237)

The effectiveness of the application of the concept of 'triple helix' in the agro-industrial complex can be considered from the standpoint of a separate region since "obvious features of agro-industrial clusters are observed at the meso level of individual regions" (Bondarenko & Maksimova, 2016). We think building an effective and efficient management system in the agro-industrial complex is possible using the triple helix concept. The subjects of management are government bodies that ensure the implementation of the strategic goals of the country's economic development; representatives of scientific centers and universities, whose activities are aimed at enhancing the implementation of scientific and technological development achievements in the national economy and the commercialization of their developments; representatives of the business community.

The use of the cluster approach to building a strategy for the development of individual regions of the Russian Federation in the field of agriculture acts as a catalyst for the overall development of the economy of the Russian Federation. The stimulus for the agro-industrial complex development is food security for the population provision, which serves as the basis for the

economic and scientific-technical development (STD) of the country and region. It also determines the welfare and health of the population. In these conditions, the main factor is the combination of state policy in the field of agro-industrial complex development by including it in priority national projects on the one hand and enhancing participation in the management system as subjects of business and science, which will modernize the entire industry and accelerate the implementation of effective mechanisms and achievements scientific and technological development into production activities. The expansion of the subjects of management makes it possible to form a different (new) system of economic thinking, carried out through the exchange of knowledge and technologies that can increase the efficiency of both the production of agricultural products and reduce the dependence on industry characteristics (natural and climatic conditions, seasonality of production, etc.).

Implementing the cluster model of the agro-cluster management system makes it possible to transform the general policy of the economy - a gradual transformation into an innovative system corresponding to international trends, activating the development trends of small and medium-sized businesses, and ensuring the use of high-performance technologies. The result of the implementation of the cluster management model in the agro-industrial complex should be an improvement of approaches to the regional development of agriculture; the creation of favorable conditions for a graded approach in the formation of a policy for the development of rural areas; the creation of new high-tech jobs, involving the intensification of the use of modern and digital technologies; taking into account the factors of import substitution and food security, etc. In addition, a specific infrastructure is being created. It makes it possible a single platform creation. A wide range of agricultural production and product sales participants can access the platform.

#### **4. CONCLUSIONS**

In our opinion, the study of the construction of the mechanism of digital transformation of agriculture, as well as the systematization of approaches and factors influencing the construction of the agro-

cluster management system in the conditions of digitalization allows us to highlight the following conclusions:

- The evolution of building a management system has historical prerequisites and factors that determine the directions that are relevant in the context of building a "new" management model in the field of the agro-industrial complex.
- Building or updating a functioning agro-cluster management system based on the "triple helix" concept allows accumulating the efforts of the major participants (by expanding them and involving science and business), to reduce the uncertainty in the agro-industrial complex and the costs of production and overproduction of agricultural products.
- The use of artificial intelligence technology in improving the management system of agro-clusters contributes to the formation of competitive advantages for the industry as a whole. On the other hand, it enhances the coordination of interaction between participants at various stages of the technology of production and sale of agricultural products (works, services); as well as directions for the development of the agro-industrial complex.
- Optimization and variation of various combinations of the use of resources of the main participants in the management system when applying the concept of the "triple helix" (science, government, and business), contributes to and affects the efficiency of agricultural production. Moreover, this influence can be both the renewal of the applied technologies and the basis for the creation of an entirely new product, using new technologies, for example, greenhouse production in vegetable growing, the use of digital technologies in breeding, etc. Combinations and different combinations of resources, production scales, and scientific potential can significantly increase the efficiency of the production process in the agro-industrial complex. This process can be different and individual for the implementation of a specific project in the industry at the level of the region or the country.

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