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THE DIGITALIZATION OF AGRICULTURE: INFRASTRUCTURE AND HUMAN RESOURCES

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Abstract

The present article is devoted to the increase of scientific knowledge in the field of economics and management of agro-industrial entities and institutions in the light of the spread of technological solutions and the global digital transformation. At the present time, the world is dealing with a shortage of food resources; however, digital technologies can help overcome the limitations in the development of agriculture, which are due to the consumption of unrenewable resource, fertility fall and soil degradation. Unlike pervasive high-intensive technologies, digital technologies can increase productivity, yield and performance while reducing the expenses and the environmental impact on agricultural landscapes. The present article upgrades the scientific perception of the economic role of digital technologies in the sustainable development of agriculture. The specific features of the development of agriculture and the agri-food market and the impact of Industry 4.0 on the transformation processes in agriculture are determined. The present research took into consideration the normative framework established by the National Program "Digital Economy of the Russian Federation", as well as other programs and projects for the digitalization of agriculture. The system of agrarian digital technologies is outlined. The best practices in the application of digital technologies in agri-food systems and global experiences in the complex digitalization of the agro-industrial complex have been analyzed. This led to the elaboration of a model of the digital environment in agriculture. The article is addressed to the specialists interested in the use of digital technologies aimed at improving the efficiency of agriculture.

Keywords: Agriculture, competences, digital ecosystem, technology solutions

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1. Introduction

The use of digital technologies in order to improve the efficiency of agriculture is currently becoming a hot topic in research. For agricultural enterprises, digital technologies possess a significant potential in the execution of different tasks, such as decreasing the volume of material and labour costs in parallel with a growth in the yielding capacity, increasing the level of sustainable development of the sector, efficiently interacting with providers, customers, development institutions and others. At the present time, both the extent of agricultural enterprises using any digital technologies and the range of digital devices used in the sector are becoming wider. The significance and insufficient elaboration of theoretic and methodological predicaments as well as applied recommendations for the introduction of digital technologies in the sector predetermine the crucial importance of this field of research. Particular applicative significance can be correlated to its straightforward connection with the tasks outlined by the National Program “Digital Economy of the Russian Federation”, as well as other programs and projects for the digitalization of agriculture, which contemplate large-scale transformations in business and infrastructure based on the principles of Industry 4.0.

2. Problem Statement

The agro-industrial sector is currently facing several tasks. Research has shown that in 2018 the world population reached 7.6 billion people and by 2050 it will surpass 9.6 billion, which calls for a significant increase in food production (Sobolevskaya, 2013). At the same time, plough lands where agricultural commodities might be produced are decreasing along with the volumes of available freshwater. Rapid urbanization is also having a significant impact on the schemes of food production and consumption.

The Sustainable Development Goal aimed at obtaining “Zero Hunger” by 2030, as established by the UN, requires food systems that are more productive and efficient, transparent, inclusive and resistant to external actions (Trendov et al., 2019). This testifies that the existing agro-industrial systems are entitled to an immediate remodelling. The execution of this task can be partially ensured by digital technologies and innovation. The so-called ongoing “Fourth Industrial Revolution” is accompanied by dynamic transformations influenced by “ground-breaking” digital innovations in different sectors. The introduction of digital technologies is one of the key strategical opportunities of the current agro-industrial sector.

3. Research Questions

The object of the current research was the economic interactions that are formed in the executive process of the mechanism for the spread of digital technologies and the formation of a digital environment in agriculture. Such environment shall allow each participant of the agri-food market and entity of the agricultural process to execute crucial tasks and to take advantage of all the technological solutions for the growth of the agribusiness without further costs by acquiring the necessary competences.

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4. Purpose of the Study

The purpose of the study is represented by the search for specific mechanism aimed at a free simple working option for the complex digitalization of the agro-industrial sector. Such option should involve as many stakeholders as possible in the strategical regulation and be controlled by the state in order to form a thorough digital environment, supplied with human resources possessing the necessary competences.

5. Research Methods

The systematization of knowledge was obtained by applying a set of principles, techniques and methods leading to objective enquiry. The impact of the penetration rate of technological solutions in the agro-industrial sector, which are aimed at providing complex digitalization, has been studied along with its features. The three basic methods of scientific and educational activities have been applied in the research process. Among the universal methods of enquiry, analysis and generalization were used in the characterization of specific elements of the introduction process of digital technologies in the agro-industrial sector, while induction and deduction were applied in the elaboration of the model of the digital environment in agriculture, which can be recommended for use in other sectors as well. Empirical methods were used in order to obtain practical knowledge while researching the process of the upcoming digital revolution of agriculture and took the form of targeted observation and experiments inside the involved economic entities. All the applied methods are consistent with the following fundamental principles: the principle of objectivity (estrangement of the researchers from the object of study); the principle of systematicity (research was carried out in 2017-2020); the principle of replicability (all the stages and phases of the research can be repeated and verified by other researchers). Among the paradigms of scientific enquiry, the concepts of positive dialectics are considered the most pertinent and applicable in the current research, since it examines a system which consists of interrelated components and antithetical elements. This system should be logically and sequentially described, which is fully legitimate.

The accuracy and foundation of the predicaments, conclusions and recommendations is grounded by a proper and qualified use of innovative methods, which suit the goal and the tasks of the research (abstract logical, grouping and computational constructive methods). The foundation and accuracy of the results and theses were obtained through the correct construction of the logics and schemes of the research. Works of outstanding Russian and foreign scholars in the fields of agro-economics, state policies in the agrarian sector, as well as economic and organizational problems of digital technologies, were used as the methodological and fundamental basis of the research.

6. Findings

Over the centuries, agriculture has gone through several revolutions, each of which gave a significant impulse to its efficiency, yielding capacity and profitability. In their forecasts, market experts agree that in the next decade the so-called “digital revolution in agriculture” will trigger a progress which

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will give to the agro-industrial sector the capacity to meet all the future requirements of the world population.

The main trigger for the development of digitalization is represented by the global range of startups and emerging technological companies. At the current stage of technological evolution, their activity can be roughly divided into 8 key areas: farm management systems (FMS); drones and robotics; data collection and aggregation for precise agriculture and performance forecasting; sensor devices; marketplaces, trading places and others. The introduction of such technologies often requires considerable financial resources and at a global level they are usually introduced in large-scale enterprises; in addition, they must be integrated in different technological systems and processes in the agri-food production chain.

The political mechanisms promoted by state authorities have become the main driving force of digitalization in many countries. As a result, a favorable environment for the maturation of electronic services and digital markets has been created. In June 2020, a Decree of the President of the Russian Federation outlined the ongoing agenda for a ground-breaking scientific, technological as well as socio-economic development of the Russian Federation aimed at reaching a so-called “digital maturity”. For this reason, the execution of projects in some crucial sectors and fields of the social life needs to be accelerated (Decree of the President of the Russian Federation, 2020). At a federal level, while forming the agenda for sustainable development, the National Program “Digital Economy of the Russian Federation” up to 2024 has been elaborated. It includes 6 federal projects: juridical regulation of the digital environment, information infrastructure, human resources for the digital economy, digital technologies, information security and digital public administration (National Program, 2018; Summary of the National Program, 2018;). However, successful results can be observed only in specific sectors in Russia, while the agrarian sector, which in the first place provides employment, falls behind.

Digitalization is gradually changing all the elements of the agri-food production chain. The structure and composition of the added value chain for specific food products is changing (Parshukov et al., 2020). Digital agriculture shall form systems with high productivity and adaptability to any changes, including climatic ones, which will lead to a growth in the level of food security.

A series of conditions, which determine the scale of digital modification in agriculture, should be taken into account according to the impact of the following premises: 1) basic conditions which promote the use of technologies (presence of technologies) – connectivity, financial availability, measures of state support and strategical programs for digitalization, computeracy and education in the field of ICT; 2) instrumental conditions – use of the Internet, use of mobile phones, use of social networks, support to the general culture of entrepreneurship and digital innovations in the agri-food sector, working skills in the use of digital technologies.

However, in spite of the forthcoming age of digitalization and ICT, 3.8 billion people still do not have the objective possibility to use telecommunication services and the vast majority of them live in rural and remote areas (Trendov et al., 2019).

In the agricultural sector, at the present time, specialized digital technologies have been introduced along with cross-cutting ones (big data; new production technologies; industrial Internet; AI; wireless technologies; robotics and sensorics elements; quantum technologies; blockchain systems; VR and AR

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technologies), which have become crucial scientific and technical areas and have the most significant impact on the development of the market, transforming agriculture as well as other sectors (Shumakova et al., 2018). For example, blockchain technologies are applied in order to identify low-quality food products in the production, distribution and processing chains; they provide the consumer with information about their origin, thus ensuring a competitive advantage.

For regulation and control purposes, special programs for the storage and elaboration of data and information aimed at improving the decision making process – the so-called ERP systems – are widely used in several areas of agricultural production. For registering the results of the veterinary and sanitary inspection of goods subject to verification and electronically processing accompanying veterinary documents, as well as gathering and elaborating information as required by the Decree of the Ministry of Agriculture of Russia No. 318 dated June 30th, 2016, the element "Mercury" was introduced in the state veterinary information system "VetIS". Its main goals are the automatic recording of incoming and outgoing products at the enterprises, the possibility to observe the circulation of lots around Russia even in case of sorting and the creation of a unified database that provides the stakeholders with access to updated information.

The digital transformation of the agro-industrial sector is currently regulated by the program "Digital Agriculture", promoted by the Ministry of Agriculture of the Russian Federation (Kotsur et al., 2020). Thanks to this project, the allocation of funds for accelerating the enhancement of the information components in agriculture is planned for the period 2019-2015; this is to be achieved by attracting financing from state programs, agribusiness representatives and privately funded sources. The strategical trends of the digitalization of the Russian agro-industrial sector can be divided into four different areas: "Smart-contracts", i.e. the creation of electronic networks with personal accounts where any economic entity can apply for state subsidies; "From the field to the dock", i.e. the elaboration of successful models for the export of the domestic production by taking into account the forecasts on the yield and the planned load of transport means and junctions; "Agrosolutions for business", i.e. the activation of the spreading process of innovative developments in the agro-industrial sector; "Earth of knowledge", i.e. the formation of a comprehensive corpus of educational content and the foundation of an organizational method for training highly qualified agrospecialists according to the current requests of the agro-industrial sector.

Seven main areas of transformation of agriculture and of scientific and technological development can be identified in the digitalization of the agro-industrial sector. As a results, in the different local entities of the Russian Federation at least seven projects shall be introduced: "Digital Technologies in Agro-Industrial Management", "Smart Field", "Smart Garden", "Digital Land Use", "Smart Greenhouse" and "Smart Farm". Such projects are based on ground-breaking, highly competitive domestic technologies, methods and algorithms and form a full innovative complex scientific and technical cycle of cross-cutting digital systems. As far as the spreading of the so-called "digitalization philosophy", the most relevant and top-priority project which needs to be studied and introduced is called "Digital Technologies in Agro-Industrial Management". The project includes: analytical instruments and databases for the elaboration of mid-term forecasts on the current state and potential development of the main agri-food markets; allocation schemes for agriculture and processing industry; evaluations on the impact of different agrarian policies on the current state of agriculture, consumer incomes, dynamics of the outer

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market of food products and agricultural raw materials, consolidate budget expenses; the monitoring of the current state and development trends of research in the field of agricultural sciences; the monitoring of the fertility of the soil in agricultural lands aimed at providing truthful information on the current state of soil for further decision making (Shumakova & Kryukova, 2016).

In rural areas the agrarian sector represents the main source of livelihoods. The digitalization of the agro-industrial sector shall significantly modify both the characteristics of work and the requirements as regards the human resources and their skills. Thus, the demand for digital skills in the agri-food human resources shall become crucial and call for a pressing need for suitable education or training. The shift towards the new technological wave caused by the spreading of practices of introduction of digital technologies justifies the need for developing new competences in the human resources following innovative training models, as required by Industry 4.0. Nowadays, applied digital technologies give agrarian universities the chance not only to train highly qualified experts by gathering analytics on the "digital footprint" of each student while designing their personal development pathway, but also to identify their talents and, as a result, customize and individualize the students' engagement. The educational process must be oriented towards digital technologies and innovations which have been already become widespread in the agro-industrial sector. Innovations such as blockchain technologies, the Internet of Things, AI, mobile technologies, remote sensing and technologies for the distributed processing of data are already widening the access of agro-industrial entities not only to information, market, production resources and finances, but also to education. Against the background of digitalization, student training should be oriented towards the acquisition not only of professional competences, but also of soft and digital skills. Education and training in agrarian universities should aim at the development of the following competences, which are crucial in a digital economy: team working ability; planning ability; the ability to design an individual development pathway and to make decisions under uncertain conditions; the ability to work in different digital platform solutions; the ability to create a training demand in any situation and to meet it with the assistance of information services; digital culture and digital hygiene while managing personal knowledge.

In order to obtain the status of leading scientific and educational centres in the training of world-class experts of future agriculture (including areas such as ecology, technologies for the monitoring of yield and livestock units, genetic engineering and alternative food sources), agrarian universities are actively developing new training programs due to the emergence of new professions bordering with the IT sector. The uniqueness of such programs consists in their implementation within the framework of consortia with the involvement of world-class specialists and includes the generation and reproduction, within the program itself, of a unique scientific content and the creation of an individual pathway that takes into account a "smart" recommendatory system. Thus, Omsk State Agrarian University is implementing a large-scale project on the genomic analysis of a collection of bioresources based on molecular gene marking. In 2021 the University will release a training program for unique world-class specialists in the field of accelerated breeding with the application of cutting-edge biotechnological, genetic as well as digital technologies within the framework of a network-based Master's Degree program.

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For training veterinarians and livestock engineers, virtual counterparts of a real production herd have been created based on the integration of the in-farm control systems of the animals, production processes and external data. The scheme for the integration of the educational process with production while training specialists in the extended group of specialties/program tracks 36.00.00 (livestock engineers and veterinarians) is presented in Figure 1. The digital counterpart is a scientific and training project that shall enable the modelling and forecasting of the productivity and diseases of animals and to correct the technological processes at the farm in due time. The review of precise and actual cases in livestock management based on such digital counterparts shall increase the chances to qualitatively analyze specific problems, familiarize the students with a wide range of approaches to its solution and give them the possibility to check the feasibility of the emerging training hypothesis while taking into account the actual conditions over a short period of time.

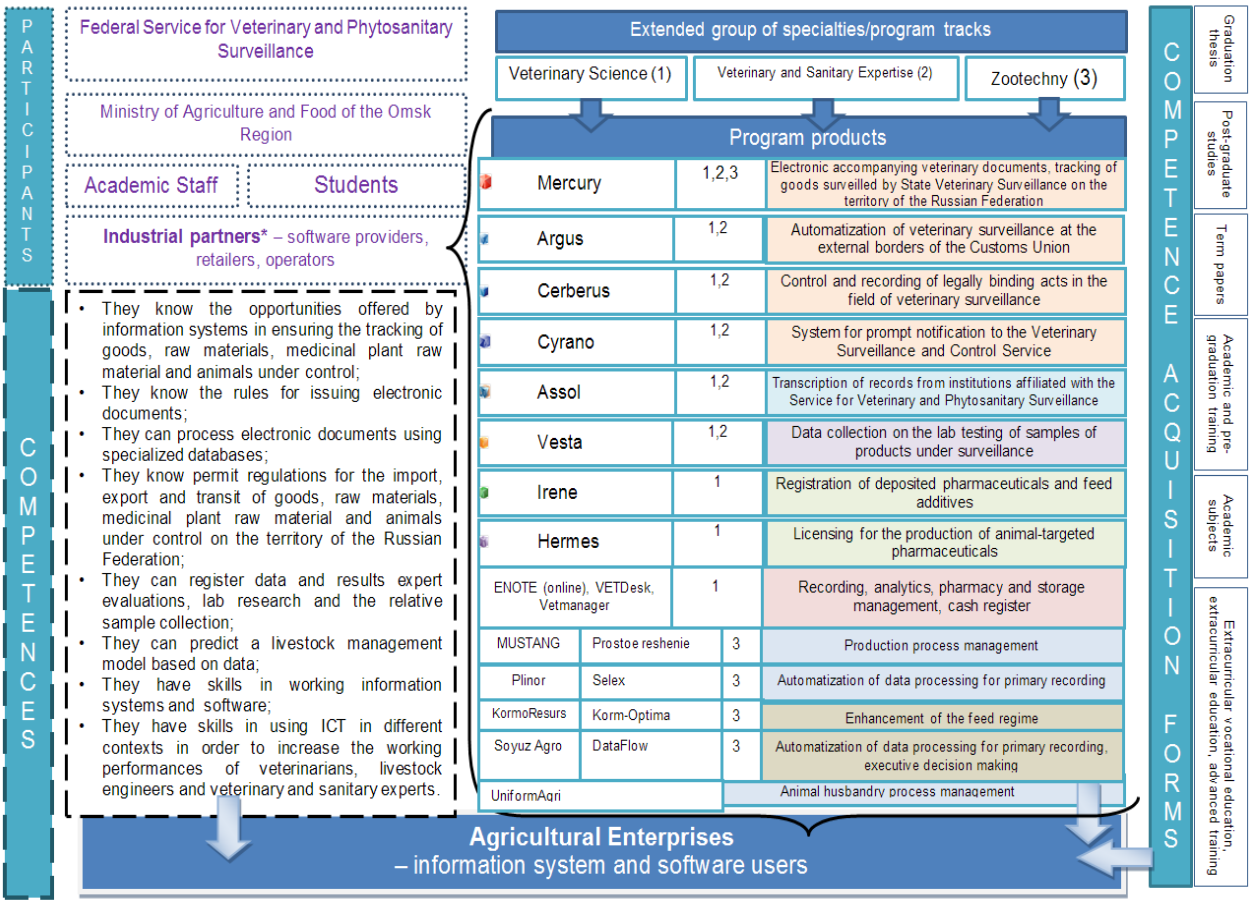

Figure 1. The model of digital education for the extended group of specialties/program tracks 36.00.00, as implemented at Omsk State Agrarian University

Likewise, operations with the virtual counterpart of a field are being implemented. In the training of specialists in the field of agrotechnologies and land use planning, research-grounded methods for the analysis of data obtained by means of remote sensing, as elaborated by scientists from leading agrarian universities, are being purposefully applied. Within the educational process, students work in real time on cases regarding the analysis of crop affection by diseases and pests as well as yield forecasting, the monitoring of natural regions and the creation of electronic maps and orthophotomaps of lands.

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Innovative digital technologies along with computing capacities allow for the application, within the educational process, of accelerated breeding methods based on the elaboration of large amounts of data, including gene mapping as well as digital and mathematical modelling of genetic sequences. Such work provides for the identification of previously unmapped genes that are responsible for economically valuable traits of the plants.

Agrarian universities are active participants in the processes of the digital transformation of the Russian agro-industrial sector: they are included in the list of world-class scientific and educational centres and implement new educational programs in the areas of big data, robotics and cutting-edge production technologies. Digital technologies, in their turn, can make agrarian education open and accessible as well as appealing for talented youth (Skosyreva & Vasyukova, 2020).

The "digital environment of agriculture" can be created in presence of the necessary technologies and human resources; a key element is represented by the readiness of the economic entities to introduce technological solutions and innovative approaches and the readiness of the state to regulate the interaction process among the participants of the IT infrastructure. This leads to the harmonization of the digital transformation of the agribusiness, supports the sustainable development of rural areas and advance the strength areas of the consumers of agricultural products.

The present research led to the elaboration of the model of the omnichannel digital environment in agriculture (Figure 2).

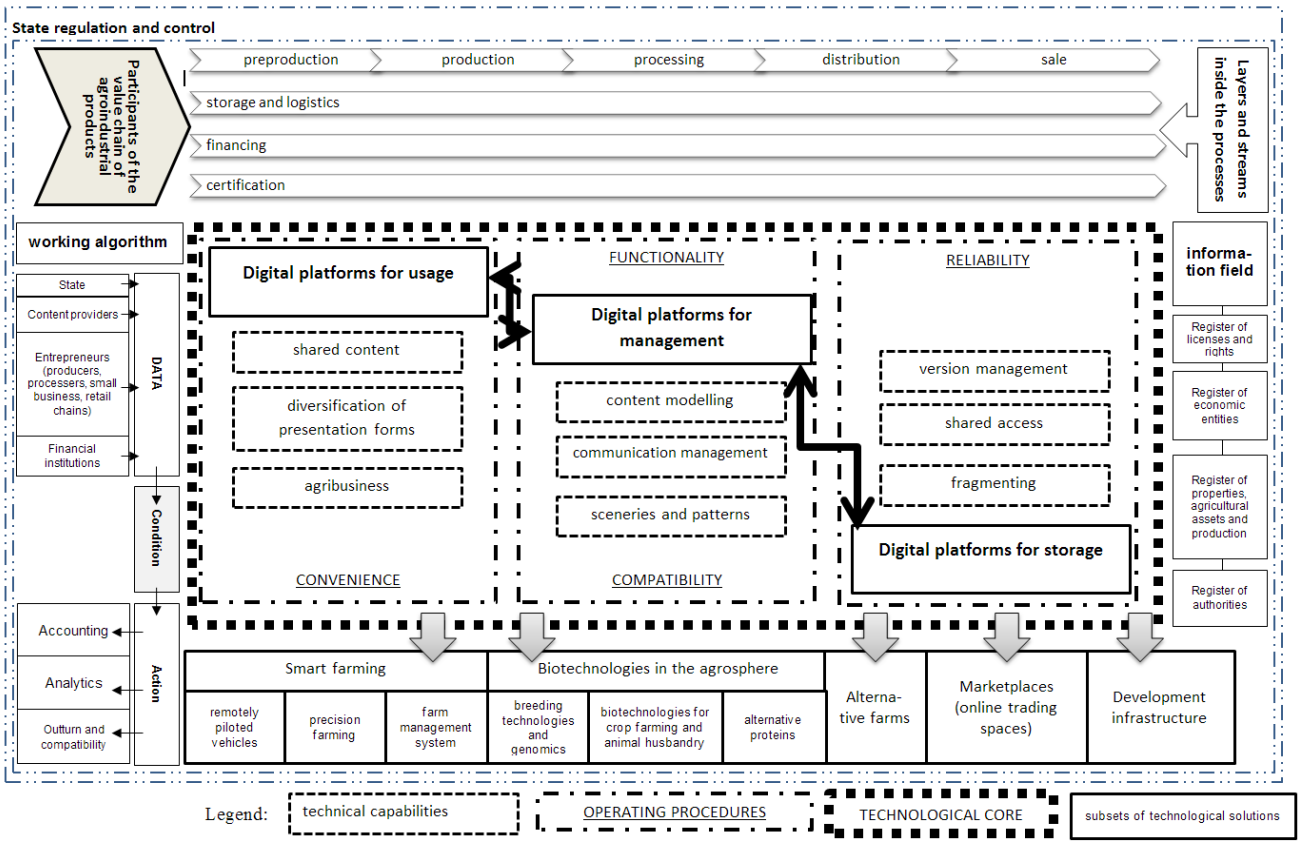

Figure 2. The model of the omnichannel digital environment in agriculture

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The technological core is represented by digital platforms for the usage, storage and management of data; the full realization of its technical potential can be obtained by meeting the functioning conditions of the platforms themselves. The information field and working algorithms of the environment in the different areas of the agro-industrial sector shall be standard ones. The peculiarity of such model is represented by the presence of streams which are determined by the processes within the sector and on the market, as well as in specific areas of technological solutions, such as smart farming and others, which have been classified by Rusbase in cooperation with iDealMachine and Agrotech Skolkovo Ventures (Zykova, 2019).

The state shall guarantee the regulation and control of the processes within the environment: high-quality provision of thorough information; adherence to the standards of digital security, hygiene and culture on part of all the participants. It shall also promote the minimization of bureaucratic and administrative barriers and rectify the laws following new models. Its final task will be to boost the transition of the companies and the population to the digital plane on one hand and the development of the national IT sector and business activity in this area on the other.

In this model, a particularly important role is played by the participants of the production, sale, storage, logistics, certification and consumption processes. The motion for the formation of a digital environment must be dictated by a common wish to intensify the digitalization of the agricultural and agro-industrial sectors; it must also provide farming units with practical instruments regardless of their scale in order to promote the automatization of their activities while focusing on the growth of the agribusiness. The digitalization of the agri-food sector will change the structure of the market and the character of work itself.

7. Conclusion

The digitalization of the agro-industrial sector represents a significant progress not only in agriculture as a whole, but also in the production of food products. Almost every form of economic activity is currently facing the need for a correct use of digital technologies and of the principles of “Industry 4.0”. This will bring about social, ecological and economic benefits, yet it might also cause a series of institutional and social problems. Differences in the access to digital technologies and services could provoke a digital gap. Small farmers and residents of remote rural areas risk falling behind the pace of the current transformation not only due to their low level of computeracy and access to digital resources, but simply because of an insufficient capacity of socio-economic integration. For an adequate introduction of digital solutions in the different areas of the agro-industrial sector, technologies are not enough by themselves. The economic, social and political environment should guarantee the necessary conditions for a complex digitalization: the presence of an advanced digital infrastructure; the promotion of computeracy and information culture; the formation of a favourable regulatory environment; the elaboration of models for the use of great amounts of data and mechanisms for the establishment of rights on data and on their use; and the popularization of electronic services and platform-based solutions from the industry of digital products.

While developing a strategy for the process of digitalization of rural areas and of agriculture, a series of factors should be taken into consideration: firstly, the absence of systematic official data on the

level of readiness in different regions and specific territories for the computerization, automatization of production processes and digitalization of agriculture; secondly, the presence of a significant gap in the introduction of digital technologies under the categories “agrarian sector vs. other sectors” and “large-scale companies vs. small business”, which is determined by the presence or absence of financial resources; finally, the opposition between the scale of the enterprises and the complexity of the introduction of digital technologies. The factor of economic rationalization is reflected by the scales. Against this background, the priority areas for the authorities in their further activities of process support and sectoral adaptation are the following: assistance in the gathering of thorough information on digital technologies and on the levels of digitalization in terms of geographical areas and social groups; elaboration of sustainable business models for the digital transformation of agriculture.

The potential advantages deriving from the digitalization of the agri-food sector call for significant changes in the production systems, life conditions, rural economy and natural asset management.

The new circumstances require a scientific insight of essentially new economic and managerial processes and relations, which emerge in the formation of the new technological paradigm in the agrarian sector. At the present time, the scientific works of theoretical and applied nature dedicated to the formation of a complex mechanism for the introduction of digital technologies are not enough. The further development of scientific postulates on the essence, role and potential of digital technologies in the agrarian economy and the elaboration of methodical and managerial instruments which might ensure a proactive introduction of such technologies in the vast majority of entities and institutions of the agro-industrial sector are of crucial importance. In this respect, the ever-growing spread of digital technologies is deemed to promote the solution of ecological problems and the preservation of natural fertility while overcoming the technological gap.

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