International Journal of Sustainable Development and Planning
Vol. 17, No. 8, December, 2022, pp. 2413-2420
Journal homepage: http://iieta.org/journals/ijsdp

Impact of Digital Farming on Sustainable Development and Planning in Agriculture and Increasing the Competitiveness of the Agricultural Business

Evgeniia Kashina[1*], Galina Yanovskaya[2], Elena Fedotkina[3], Andrey Tesalovsky[4], Ekaterina Vetrova[5], Aigul Shaimerdenova[6], Madina Aitkazina[7]

[1] Russian Politics Department, Lomonosov Moscow State University, Moscow 119991, Russia
[2] Department of Foreign Language for Technological Specialties, Moscow Aviation Institute, Moscow 125993, Russia
[3] Department of Russian and Foreign Languages, Russian University of Transport, Moscow 127994, Russia
[4] Department of Urban Cadastre and Geodesy, Vologda State University, Vologda 160000, Russia
[5] Department of Finance and Business Analytics, The Kosygin State University of Russia, Moscow 117997, Russia
[6] Department of Land Resources and Cadastre, Kazakh National Agrarian University, Almaty 050100, Kazakhstan
[7] Department of Marketing and Logistics, Turan University, Almaty 050013, Kazakhstan

Corresponding Author Email: jennymt@mail.ru

https://doi.org/10.18280/ijsdp.170808

Received: 21 October 2022
Accepted: 21 December 2022

Keywords:
agricultural enterprises, digital farming, digital farming technologies, digitalization

ABSTRACT

To develop agriculture, it is crucial to introduce digital farming. This is a fundamentally new management strategy based on digital technologies associated with the use of geographic information systems of global positioning, onboard computers, and smart equipment, as well as managerial and executive processes that can differentiate the methods of farming, fertilization, and adding chemical ameliorants and plant protection products. The study aims at determining the applied aspects and key components within a system of digital farming as a tool for the sustainable development of the agricultural business. The authors chose a mixed type of research, with a predominance of qualitative research methods. In particular, to collect data, the authors analyzed scientific sources on the research problem and conducted an expert survey measuring the degree of consistency of expert opinions with mathematical processing of the results obtained. It was determined that in Russia, it is necessary to consistently introduce the use of digital farming. This includes the introduction of parallel stirring, the ability to turn off the sections of the seeder on the floors, the re-equipment of crop protection sprayers to turn off the sections on the floors, and the acquisition of new equipment for differentiated fertilization. The authors conclude that the introduction of digital farming by agricultural producers is a tool for sustainable development and planning in agriculture and increasing the competitiveness of the agricultural business since it increases the economic (increased yields, reduced crop losses, increased land bank efficiency), environmental (production in risky farming areas), and social (increasing the level of personnel qualification and social standards) efficiency of their activities.

1. INTRODUCTION

Under modern conditions characterized by such trends as globalization [1], big data management [2], and digitalization [3], the scientific literature in the field of agriculture actively discusses the optimal conditions for the development of agriculture.

Due to integration and globalization, as well as the cross-border movement of goods and services, it has become essential for enterprises to have such tools that would guide and adjust their activities to gain competitive positions in international markets [4]. Digitalization for the agricultural business is the basis for effective functioning due to the ability of technologies to optimize costs, identify bottlenecks in business processes [5], follow patterns, and forecast events [6]. The result of digital transformation is efficiency, competitiveness, and the creation of new values [7].

Modern digital technologies significantly (in some cases dramatically) affect the process of agricultural production, in particular, the development of crops. High-quality tillage [8], sufficient fertilization [9], optimal soil moisturization [10], and other measures are important conditions for ensuring the sustainable development approach that significantly increase the production of agricultural products low in nitrogen and with the lowest costs of material, labor, information, natural, and other resources. The above-mentioned results can be achieved by applying modern methods of management [11], mechanization [12], and automation of production processes using innovative digital technologies [13].

The ongoing processes contribute to the intensification of agriculture and the expansion of enterprises. From the modern understanding of the future, the sustainable development approach focuses on the preservation of the environment [14] and the development of safe technologies [15], thereby making enterprises use digitalization as an opportunity to renew technologies of both production and management processes [16].

Therefore, our research aims at finding a balance, especially in Russia, between the need to introduce the necessary digital innovations for the implementation of sustainable development and economic feasibility, i.e. the availability of the necessary financial resources for the implementation and the effectiveness of implemented innovations.

To solve the research tasks, the study uses mixed data collection methods (qualitative and quantitative methods). Since Russia is a zone of risky agriculture [17], it is advisable to introduce digital innovations with due regard to the diversity of climatic conditions and the heterogeneity of fields to minimize risks and optimize costs. To comprehend these features, we interviewed experts. This method is actively used in studies on agriculture and ecology to obtain information about the research object and its possible changes [18].

The expert survey allows for determining the applied aspects and key components of the system for introducing digital farming as a tool for the sustainable development of the agricultural business.

The rest of the article is organized in the following manner. The next section reviews the scientific literature on the use of digital farming technologies and presents and discusses research methods and results. The largest section of the article covers such topics as (1) the use of digital farming technologies in relation to types of agricultural work; (2) the analysis of digital applications for the implementation of digital farming technologies; (3) the definition of promising and demanded digital farming technologies for the current agricultural business in Russia.

Literature overview

According to Samer and Subramaniya Raman [19], the agricultural sector in terms of digital maturity is classified as one of the most digitized (the highest level of digital integration). According to the Food and Agricultural Organization report [20], the probability of implementing certain digital technologies in the agricultural sector by 2025 is as follows: 88% for the Internet of things; 86% for big data analytics; 80% for e-commerce; 75% for cloud computing, storage, and energy generation, 62% for artificial intelligence; 54% for work; 50% for biotechnology. The integration of the agricultural industry with technology allows automatically determining soil characteristics and conditions [21]; making decisions using sensors and mechanisms to ensure the volume and quality of products, as well as the conservation of agricultural land [22].

According to some scholars, the priority areas for introducing digital technologies into crop production processes [23] are those areas of development that can increase production volumes [24], improve quality [25], reduce production costs [26], and accelerate return on investment [27] in the near future.

When studying this research topic, scholars widely use such concepts as precision agriculture, precision farming, and smart farming [28-30]. Precision agriculture is regarded as the precise application of agricultural resources based on the analysis of soil, weather, and crop requirements to maximize sustainable crop productivity, quality, and profitability [28, 29]. Smart farming is based on the implementation of information and computer technologies in machines, equipment, and sensors of agricultural production systems, which enables the generation of a large amount of data and information with their gradual introduction into the decision-making process. Unlike classical agriculture, where the necessary operations are determined for each field, smart farming determines the actions per square meter, or even for a single plant [30].

Within the framework of this study, the term "digital farming" is used which is interpreted as a fundamentally new management strategy in agronomy with the help of digital technologies and new technical means and involves the implementation of technological measures for growing plants with due regard to the spatial heterogeneity of fields [31].

The studies conducted show that the digital development of agricultural production provides for the introduction of resource-saving and digital farming technologies by agricultural enterprises. These include soil-protective, innovative, and competitive technologies [32], contributing to the structural and technological restructuring of producers and building up the economic potential of the agricultural sector of the economy [33].

According to Vibhute and Bodhe [34], digital farming technologies clearly define agrochemical and agrophysical characteristics of fields, the compilation of electronic maps with the relevant indicators, and the introduction of agrochemicals with due regard to the various needs of crops in certain areas of the field. A necessary condition for their use is the exact orientation of units according to the GPS [35].

Based on the study of international experience, it was confirmed that the yield depends on natural conditions by 80% [36]. Under digital farming systems, the impact of weather and climate on the efficiency of crop production is reduced to 20%, while technologies and management in agriculture account for 80% [36].

The systematization of digital farming technologies is shown in Table 1.

To understand the application of digital farming technologies in agriculture, we should briefly explain what they are.

Table 1. Digital farming technologies (compiled by the authors)

<table>
<tr><th colspan="6">Basic digital farming technologies</th></tr>
<tr><td colspan="2">Global Positioning System (GPS)</td><td colspan="2">Geographic Information System (GIS)</td><td colspan="2">Remote sensing</td></tr>
<tr><td colspan="2">It determines the location of fields so that input resources (seeds, fertilizers, pesticides, herbicides, irrigation water) are applied to an individual field based on performance criteria and their previous use</td><td colspan="2">It provides information about the topography of fields, soil types, crop yields, etc. to determine the relationship between various elements and yields in a particular area</td><td colspan="2">It allows obtaining spatially and temporally distributed information to identify and analyze various crops and soils in fields</td></tr>
<tr><th colspan="6">Digital applications
Applied technologies of digital farming</th></tr>
<tr><td>Parallel steering</td><td>Rate management</td><td>Soil analysis</td><td>Field monitoring (drones, unmanned aerial vehicles)</td><td>Satellite monitoring</td><td>Weather monitoring</td></tr>
</table>

Parallel steering allows the system to control the tractor itself and not trample the plants [26]. According to relevant studies [17], parallel steering requires an autopilot and a course indicator with the RTK (Real Time Kinematic) signal or without it (service or custom RTK station). However, an RTK base station is a device that sends a correction signal (corrections) over a GPRS connection, which improves the accuracy of conventional GPS positioning up to 2.5 cm. These options help to avoid certain problems, such as gaps and overlaps. If more than five agricultural machines need an RTK signal at the same time, it is more profitable to build an individual station (the radius of its signal is approximately 30 km). If there are fewer machines, it is more expedient to use the appropriate service of specialized companies. Parallel steering based on the use of thrusters, GPS navigators, and autopilots allows for optimizing farming; significantly reducing the cost of fuel, seeds, and fertilizers due to the differentiated application of seeds, fertilizers, and plant protection products; as well as ensuring the accuracy of operations.

Rate management means controlling seed sowing rates and applying plant protection products and fertilizers, which allows, for example, saving at least 2-3% of seeds (if fields are irregularly shaped, then this option will save up to 5% of seeds), i.e. 2-3 euros per 1 ha. Thus, the technology has a fairly short payback period and proportionally depends on the land bank of an enterprise [37]. It allows not only saving on the cost of plant protection products but also reducing the damage to plants from double tillage, which ultimately affects the yield.

Agrochemical soil analysis with sensor equipment allows for assessing soil fertility, obtaining data on soil suitability for growing a particular crop, optimizing the nutrition system, and reducing fertilization costs [38].

Monitoring crops using satellites or drones to obtain comprehensive information about the state of soils and plants contributes to the rapid adoption of management decisions on tillage or pest control. Based on weather monitoring, it is possible to determine the best periods for starting a sowing campaign, irrigation, fertilization, and adding plant protection products; as well as reduce the cost of water, plant protection products, and fertilizers.

The introduction of digital farming technology and management into the Russian agro-industrial complex requires significant financial costs. Considering the relatively low profitability of agriculture, especially small- and medium-sized agricultural enterprises [39], the Russian agricultural producers are in no hurry to introduce expensive innovations and are limited to minimal investments in digital farming, i.e. digital applications [40] available for Android, iPad, iPhone, etc. [41].

However, there is a gradual understanding that enterprises that do not follow the principles of sustainable development and introduce digital farming technologies into production even in the medium term will eventually become uncompetitive [42].

All of the above determines the novelty of the study concerning the impact of digital farming on the sustainable development of agriculture and increasing the level of planning and competitiveness of the agricultural business. The novelty of the study is also determined by the fact that so far the relationship between the types of agricultural work and the use of digital farming and the most promising and popular digital farming technologies, which are currently most often implemented by agricultural enterprises in Russia and countries with similar conditions for the development of agriculture (such as the Republic of Kazakhstan), have not been determined. We systematized modern digital applications for the introduction of digital farming technology for agricultural producers.

2. METHODS

To solve the tasks set, we used a mixed type of research, including the use of qualitative and quantitative methods. Qualitative methods comprised the analysis of scientific sources on the research topic and an expert survey. The concordance between expert opinions and mathematical results was measured. The study was conducted in three stages from February to April 2022 using the resources and capabilities of the following universities: Lomonosov Moscow State University, Moscow Aviation Institute, Russian University of Transport, Vologda State University, and Kazakh National Agrarian University.

At the first stage, we studied scientific and analytical works on the research topic. While analyzing such publications, we determined the relationship between the types of agricultural work and the use of digital farming technologies, as well as systematized modern digital applications for their implementation by large- and small-sized Russian agricultural producers. The relevant scientific sources were selected from the Russian Science Citation Index, Web of Science, and Scopus using such keywords as "digitalization", "digital farming", "e-agriculture", "smart farming", "e-farming" and "precision farming", and "precision agriculture". All the selected publications were no older than 10 years.

At the second stage, we had online communication with the experts. The expert survey was carried out in Russian via e-mail. Within the framework of the survey and due to the lack of well-reasoned scientific research on the most promising and sought-after digital farming technologies in Russian agrarian business, differentiated by types of agricultural work, the experts were asked the following question: "What are the most promising and popular digital technologies that are most often implemented by agricultural enterprises in Russia for various types of agricultural work?".

We sent e-mails containing this question to 58 experts, including 11 heads of agricultural enterprises that use precision farming, 33 managers and distributors of agricultural IT companies and teachers of specialized universities; 13 practitioners in the field of digital technologies in the agricultural sector. The experts were asked to substantiate their answers in a free form. Fifty-three experts filled out the form. All respondents were informed about the objective of the survey and our intention to publish its results in a generalized form. When processing the expert responses, the percentage of expert references to digital farming technologies was calculated, which is the number of the respondents' answers in which this technology was mentioned in relation to the total number of responses received.

After receiving the answers, we sent the experts a second e-mail. Depending on the significance of digital farming technologies, they were asked to arrange them on a scale of order and assign points. When re-applying, digital farming technologies were considered, and the percentage of expert mentions of which in previous answers exceeded 50%. Next, the rank of each technology was determined, according to the points attributed by the experts.

For a more objective analysis of the data obtained during the expert survey, the compliance of expert opinions was mathematically measured using Kendall's coefficient of concordance (W):

$$W = {}^{12S}/_{n^2(m^3 - m)}$$

where, S is the sum of the squared deviations of all the ranks given to each digital farming technology from the average value; n is the number of experts; m is the number of assessed digital farming technologies.

Further, the information obtained during the expert survey was processed to determine the impacts of digital farming technologies, form a rank transformation matrix, and calculate the arithmetic mean of impacts for each technology. The final impacts identify the significance of digital farming technologies from the viewpoint of experts.

3. RESULTS

While analyzing the relevant scientific literature, we determined the relationship between the types of agricultural work and the use of digital farming technologies (Table 2).

We also systematized modern digital applications for the implementation of digital farming available for Android, iPad, iPhone, etc. and used by both large and small agricultural producers in Russia (Table 3).

Table 2. The application of digital farming technologies depending on the types of agricultural work

Types of agricultural work	Technologies					
	Soil analysis	**Parallel steering**	**Rate management**	**Drones, unmanned aerial vehicles**	**Satellite monitoring**	**Weather monitoring**
Creating task maps for variable rates governing the application of fertilizers, ameliorants, and seeds	+					
Determining the field potential	+					
Depth of soil surface	+					
Yield forecast	+					
Crop rotation planning	+					
Pre-sowing tillage		+	+			
Differentiated fertilization		+	+			
Sowing		+				
Differentiated sowing			+			
Application of plant protection products		+				
Harvesting		+				
Precise spraying			+			
Monitoring the state of crops				+	+	
Field measurement				+	+	
Mapping				+		
Simultaneous application of plant protection products and fertilizers				+		
Protective functions				+		
Crop area structure					+	
History of fields					+	
Monitoring the current weather conditions in the fields						+
Local weather forecast for operations planning						+
Prevention of plant diseases						+
Yield analysis						+

Note: compiled by the authors after analyzing scientific literature

Table 3. Digital applications for the introduction of digital farming technologies

Direction	Digital applications	Functions
Monitoring plant health and crop growth conditions	BeCrop, Sirrus	Monitoring field conditions
	EOS Crop Monitoring	Analysis of weather conditions, stages of plant development, optimal amount and time for sowing or fertilizing, field zoning in GIS
	GeoPard Agriculture	Creating a map for the application of agents (fertilizers and plant protection products) with a variable rate; field zoning according to historical yield data, etc.
Protecting crops from diseases	Farm Dog, Taranis Scout	Field scouting and crop disease identification
	Field Prophet, Valley Insights	Plant disease risk prediction
	Drift	Protection priority
Plant nutrition	eKonomics by Nutrien	Identification of a deficiency of vital organic compounds in the soil
	Crop Nutrient Advisor	Identification of nutrient deficiencies using crop images
Equipment monitoring	DropControl	Control of the irrigation system
	John Deere Operations	Management of field equipment and its functioning

Note: compiled by the authors after analyzing scientific literature

Table 4. The most prospective and highly-demanded digital farming technologies

Technology	Digital tool	%*	Ranking	Impact
Parallel steering	Autopilot and course indicator	85%	1	0.43
Differentiated application of fertilizers, seeds, and plant protection products	Equipment for the differentiated application of fertilizers, seeds, and plant protection products	74%	2	0.32
Sprayer section shutdown when applying fertilizers and plant protection products	Sprayer section shutdown system	66%	3	0.10
Disabling sections of the seeder when sowing crops	System for the automatic shutdown of seeder sections and their equipment with sensors monitoring the process of seeding	60%	4	0.08
Alternative fertilization, plant protection, and field monitoring	Drones, unmanned aerial vehicles, satellite monitoring	55%	5	0.07

Note: based on the expert survey, * –% of expert references.

The expert survey has revealed the most promising and highly-demanded digital farming technologies which are currently implemented by agricultural enterprises in Russia (Table 4).

According to Kendall's coefficient of concordance (W) (W = 0.71), it can be argued that the expert opinions are coherent since the value of W>0.5 indicates the objectivity of the survey results. This circumstance helps determine the impacts of the most promising and highly-demanded digital farming technologies.

In conformity with the results, the most promising and popular digital farming technologies are parallel steering (0.43) and differentiated application of fertilizers, seeds, and plant protection products (0.32).

4. DISCUSSION

Traditionally, the system of digital farming includes the following stages: data collection; the analysis of the collected information; the adoption of agrotechnical decisions (based on the above-mentioned analysis). The corresponding scientific literature has shown that such digital farming technologies as parallel steering, rate management, soil analysis, the use of drones and unmanned aerial vehicles, and satellite-based and weather monitoring can be used in almost all types of agricultural work (Table 2). The systematization of digital applications for the implementation of digital farming technologies (Table 3) allows us to determine the main areas of their use (condition monitoring, disease protection, crop nutrition, and equipment operation monitoring) and such functions as determining the amount and time of sowing/applying fertilizers, zoning fields, and managing and controlling field equipment, depending on their specific role in monitoring field and weather conditions, as well as stages of development and diseases of plants.

Considering the significant financial constraints of agricultural producers [43] and high rates for using attracted funds [44], the experts claimed that the adoption of digital innovations requires the selection of the most effective growth points for crop production. To attain this end, it is necessary to substantiate the priority areas for digitalization in the practical activities of farmers. The use of digital farming technologies involves the division of fields into management zones based on homogeneous characteristics. The most important criterion that determines the economic potential of an individual field is the type of soil [35]. The experts argue that such technologies become available and effective for a land bank of 500 ha. Today about 30% of agricultural enterprises are gradually adopting digital farming technologies but usually, they are limited to only one innovation, for example, an autopilot or heading indicator to prevent overlaps and gaps in the fields.

According to the experts, the first step in the application of digital farming technologies is parallel steering since its adoption and mastering almost completely solve the above-mentioned problems, which reduces costs, satisfies the need for equipment, and speeds up field work [32]. The studies [30, 34] confirm that parallel steering with standard tillage eliminates overlaps and gaps, which can reduce wear and tear on agricultural machinery, the time of the corresponding operations, the amount of fuels and lubricants, etc.

The simplest option for digital farming technologies is rate management. It can be used in the next stage of farming (sowing) to disable planter sections on overlaps. Not only seed material is saved but it also becomes possible to obtain more even seedlings, increase work productivity by sowing in optimal agrotechnical terms, and use less fertilizers before sowing [27], regardless of the increase in yield due to the improved distribution of grains in the soil [28].

The next stage when it is expedient to use digital farming technologies in Russian conditions is a system of measures to combat weeds, diseases, and pests. 66% of the respondents have concluded that the main task of applying such technologies is the re-equipment of sprayers to disable sections on overlaps. The study [31] confirms that the automatic shutdown of the sprayer sections saves from 10 to 20% of plant protection products, depending on the geometry and topography of fields. A sprayer without an autopilot that does not drive along the aisle tramples up to 3% of the crop yield.

The most difficult element of digital farming technologies is fertilization since this stage of growing crops requires significant resources. It is extremely difficult to transform the existing equipment for the differentiated use of fertilizers. It seems to be easier to purchase new machines but this requires investments. However, the federal government needs support and a special state program due to technological and financial limitations [3, 45].

The studies conducted [19, 33] show that the rate of fertilization should be calculated according to agrochemical analysis since the amount of mineral fertilizers required by certain crops depends both on their biological characteristics and on the agrochemical properties of the soil. After analyzing the agrochemical properties of the soil, a map (grid) of micro- and macroelements is created, which can significantly vary within the same field. This predetermines a different rate of fertilization within various soil structures [33]. Notwithstanding the foregoing, fertilization under digital farming technologies requires not only appropriate equipment and machinery but also a clear understanding of the need to create a field map based on the agrochemical properties of its soil [46, 47]. This will combine digital technologies with the actual data of a particular field for the effective use of available resources [19].

The experts emphasized that the major component of building truly digital farming within a particular enterprise is the availability of appropriate agricultural machinery since auxiliary tools and purchased digital gadgets will not be enough to re-equip production without modern carriers of these devices. The primary task of agricultural enterprises on the way to digital farming is to determine which technologies and for which purposes they need most and start purchasing this equipment with due regard to the available machinery and financial capabilities. According to the interviewed experts, only an integrated approach to the implementation of digital farming technologies will provide the expected economic results.

From the standpoint of sustainable development, the implementation of digital farming should have an economic, social, and environmental effect. The higher efficiency of an enterprise through investments in certain digital farming technologies can be based on both reducing costs and increasing crop yields. Such technologies are aimed primarily at economic efficiency and soil protection, increasing productivity per hectare of land, reducing crop losses, and growing the efficiency of the land bank. The introduction of digital technologies based on strip-till or no-till farming provides an opportunity for agricultural producers to save moisture, control the seeding rate and create maps for sowing and fertilizing, i.e. they can work in risky farming areas and balance climate changes to achieve an environmental effect.

The introduction of digital farming technologies involves the formation and processing of large data arrays, which requires an appropriate qualification of the enterprise's personnel and the acquisition of professional skills and, accordingly, leads to a higher level of remuneration.

5. CONCLUSION

The introduction of digital technologies involves the implementation of several actions aimed at increasing the level of sustainable development and planning in agriculture. First, it is necessary to develop a clear action plan and an algorithm for measuring results. The subsequent management of digital technologies in agriculture includes several stages: data collection; analysis of the collected information; adoption of agrotechnical solutions (based on analysis). In this connection, the management of digital technologies in agriculture involves the formation and processing of large data arrays. This requires an appropriate level of qualification of the personnel of the enterprise and the acquisition of professional skills and, accordingly, leads to a higher level of remuneration.

The use of digital farming technologies has the following results: firstly, to make the process of agricultural production more transparent, understandable, manageable, and safe based on improving the production organization system (using digital tools), which facilitates and accelerates the interaction between all participants in production processes and at different management levels; secondly, to increase the efficiency and ability to control production costs (using the main material resources, machinery, equipment, working hours, etc.); thirdly, to overcome certain pain points of growing crops, such as overspending of seed, plant protection products, fuels and lubricants, fertilizers, etc. thanks to the phased introduction of digital farming technologies, as well as to significantly improve the accuracy and reduce the time of performing all fieldwork, which is a source of additional resource savings of an agricultural enterprise forming the cost of production; fourthly, to optimize the timing of fieldwork using the data of modern weather services and other digital assistants, which is the key to timely fieldwork and rich harvests in the future.

As the study results have shown, it is necessary to consistently use digital farming technologies in Russia, including the introduction of parallel stirring, the ability to turn off the sections of the seeder on the floors, the re-equipment of crop protection sprayers to turn off the sections on the floors, and the acquisition of new equipment for differentiated fertilization.

The introduction of digital farming by agricultural producers is a tool for sustainable development since it contributes to an increase in economic (growing yields, reduced crop losses, more capacity utilization of land bank), environmental (production in risky farming areas), and social efficiency (improved staff qualifications, higher social standards) of their activities. However, this study has limited expert sampling. Further research might focus on the development of interaction between state and business to attract investment in the digitalization of agriculture, as well as the economic, environmental, and social effects of the introduction of digital farming in Russia and countries with similar climatic conditions and state of agriculture.

REFERENCES

[1] Eugene, M., Janvier, M., Tuyisenge, E., Lonzy, O. (2020). Assessment of poultry production system in Rwanda, a case study in Nyagatare district. American Journal of Animal and Veterinary Sciences, 15(1): 1-9. https://doi.org/10.3844/ajavsp.2020.1.9

[2] Krogh, M.A., Enevoldsen, C. (2012). Management of data for health performance measurement in the industrialized dairy herd. American Journal of Animal and Veterinary Sciences, 7(4): 159-174. https://doi.org/10.3844/ajavsp.2012.159.174

[3] Chen, L., Su, S. (2022). Optimization of the Trust Propagation on Supply Chain Network Based on Blockchain Plus. Journal of Intelligent Management Decision, 1(1): 17-27. https://doi.org/10.56578/jimd010103.

[4] Lagodiienko, V., Popelo, O., Zybareva, O., Samiilenko, H., Mykytyuk, Y., Alsawwafi, F.M.A.S. (2022). Peculiarities of the management of the foreign economic activity of enterprises in current conditions of sustainability. International Journal of Sustainable Development and Planning, 17(4): 1215-1223. https://doi.org/10.18280/ijsdp.170420

[5] Gladilina, I., Pankova, L., Sergeeva, S. and Kolesnik, V. (2022). The effect of using information technologies for supporting decision-making in the procurement management of an industrial enterprise on reducing financial costs. Indian Journal of Economics and Development, 18(2): 367-373.

[6] Gasparian, M.S., Kiseleva, I.A., Titov, V.A., Sysoev, N.A., Chernysheva, E.N. (2021). Socioeconomic development: Search for optimal models for forecasting inflationary processes. International Journal of

Criminology and Sociology, 10: 472-478. https://doi.org/10.6000/1929-4409.2021.10.55
[7] Richter, K.K., Pakhomova, N.V. (2018). Digital economy as the innovation of the 21st century: Challenges and chances for sustainable development. Problemy Sovremennoi Ekonomiki, 2: 22-23.
[8] Sheudzhen, A.K., Gutorova, O.A., Hurum, H.D., Petrik, G.F., Doroshenko, T.N. (20021). Dynamics of the nutrient contents in the soils of rice fields in Kuban (Russia). Annals of Agri Bio Research, 26(1): 52-59.
[9] Nugmanov, A.B., Mamikhin, S.V., Valiev, K.K., Bugubaeva, A.U., Tokusheva, A.S., Tulkubaeva, S.A., Bulaev, A.G. (2022). Poly-species phytocenoses for ecosystem restoration of degraded soil covers. OnLine Journal of Biological Sciences, 22(3): 268-278. https://doi.org/10.3844/ojbsci.2022.268.278
[10] Shchemeleva, G.V., Tsyndra, L.V., Yakovlev, M.A., Gavrilik, V.E., Karkhardin, I.V., Galeev, R.R., Petrov, A.F., Dobryanskaya, S.L. (2021). Effect of irrigation on maize (Zea mays) productivity and agrochemical indicators of leached chernozem in the forest-steppe in the Novosibirsk region. Research on Crops, 22: 759-763. https://doi.org/10.31830/2348-7542.2021.127
[11] Khavanova, N.V., Morozov, V.Yu., Gubachev, N., Morozova, T., Duborkina, I. (2022). The mechanism of forming state governance of territories. International Journal of Ecosystems and Ecology Science, 12(3): 109-116. https://doi.org/10.31407/ijees12.314
[12] Nasiyev, B.N., Bekkaliyeva, A.K., Vassilina, T.K., Shibaikin, V.A., Zhylkybay, A.M. (2022). Biologized technologies for cultivation of field crops in the organic farming system of West Kazakhstan. Journal of Ecological Engineering, 23(8): 77-88. https://doi.org/10.12911/22998993/150625
[13] Antiabong, J.F., Ngoepe, M.G., Abechi, A.S. (2016) Semiquantitative digital analysis of polymerase chain reaction-electrophoresis gel: Potential applications in low-income veterinary laboratories. Veterinary World, 9(9): 935-939. https://doi.org/10.14202/vetworld.2016.935-939
[14] Tsenina, E., Danko, T., Kiselev, V., Chaykovskaya, L., Epstein, N., Rauskiene, O., Sekerin, V. (2022). Cluster analysis of the expenditures for environmental and technological innovations in sustainable development policy formation. Journal of Environmental Management and Tourism, 13(1): 63-74.
[15] Narladkar, B.W. (2018) Projected economic losses due to vector and vector-borne parasitic diseases in livestock of India and its significance in implementing the concept of integrated practices for vector management. Veterinary World, 11(2): 151-160. https://doi.org/10.14202/vetworld.2018.151-160
[16] Bacco, M., Barsocchi, P., Ferro, E., Gotta, A., Ruggeri, M. (2019). The digitization of agriculture: A survey of research activities on smart farming. Array, 3-4: 100009. https://doi.org/10.1016/j.array.2019.100009
[17] Yakushev, V.V. (2016). Precision Farming: Theory and Practice: Monograph. FGBNU AFI, Saint Petersburg.
[18] Debnath, T., Bera, S., Deb, S., Pal, P., Debbarma, N., Haldar, A. (2017) Application of radio frequency based digital thermometer for real-time monitoring of dairy cattle rectal temperature. Veterinary World, 10(9): 1052-1056. https://doi.org/10.14202/vetworld.2017.1052-1056
[19] Samer, D.M, Subramaniya Raman, M.K. (2020). E-farming: A breakthrough for farmers. International Journal of Engineering Research & Technology, 9(7): 834-838.
[20] FAO. (2021). The State of Food and Agriculture 2021. Making Agrifood Systems More Resilient to Shocks and Stresses. FAO, Rome. https://doi.org/10.4060/cb4476en
[21] Balova, S., García de Velazco, J., Polozhentseva, I., Chernavsky, M., Shubtsova, L. (2021). The formation of the concept of smart sustainable city with the purpose of environmental protection. Journal of Environmental Management and Tourism, 12(5): 1269-1275.
[22] Stepnykh, N.V., Nesterova, E.V., Zargaryan, A.M., Zhukova, O.A., Stepnykh, T.V. (2018). The Digitalization of Agro-Technological Management. OOO "Kurtamyshskaya tipografiya", Kurtamysh.
[23] Dutbayev, Y., Sultanova, N., Tsygankov, V., Islam, R., Kuldybayev, N. (2020). A comparison study of biotic factor's effect on photosynthesis processes of soybean by usingmultispeq device on photosynq org platform. ARPN Journal of Engineering and Applied Sciences, 15(22): 2627-2630.
[24] Munyua, H., Adera, E. (2013). Emerging ICTs and their potential in revitalizing small-scale agriculture. Agricultural Information Worldwide, 2(1): 3-9.
[25] Tzounis, A., Katsoulas, N., Bartzanas, T., Kittas, C. (2017). Internet of things in agriculture, recent advances and future challenges. Biosystems Engineering, 164: 31-47. http://dx.doi.org/10.1016/j.biosystemseng.2017.09.007
[26] Awuor, F., Raburu, G., Onditi, A., Rambim, D. (2016). Building e-agriculture framework in Kenya. Journal of Agricultural Informatics, 7(1): 75-93. https://doi.org/10.17700/jai.2016.7.1.244
[27] Maloku, D. (2020). Adoption of precision farming technologies: USA and EU situation. Practical Application of Science, 8(22): 7-14.
[28] Hussain, S.M., Hussain, K., Farwah, S., Lone, S., Rashid, M. (2021). Precision agriculture-smart farming: The future of agriculture. In: Recent Advances in Agriculture, Engineering and Biotechnology for Food Security, Mahima Research Foundation and Social Welfare, Karaundi, 167-171.
[29] Walter, A., Finger, R., Huber, R., Buchmann, N. (2017). Opinion: Smart farming is key to developing sustainable agriculture. Proceedings of the National Academy of Sciences, 114(24): 6148-6150. http://dx.doi.org/10.1073/pnas.1707462114
[30] Okediran, O.O., Ganiyu, R.A. (2019). E-agriculture reviewed: Theories, concepts and trends. Journal of Engineering and Technology, 4(1): 125-130. http://dx.doi.org/10.46792/fuoyejet.v4i1.366
[31] Narmilan, A. (2017). E-agricultural concepts for improving productivity: A review. Scholars Journal of Engineering and Technology, 5(1): 11-17.
[32] European Parliament, Directorate-General for Parliamentary Research Services, Daheim, C., Poppe, K., Schrijver, R. (2016). Precision Agriculture and the Future of Farming in Europe. European Union, Brussels. https://doi.org/10.2861/020809
[33] Kaviarasan, S., Vanitha, M. (2022). E-farming management system using data mining techniques. International Journal of Intelligent Unmanned Systems,

10(2/3): 257-266. https://doi.org/10.1108/IJIUS-05-2020-0018
[34] Vibhute, A., Bodhe, S.K. (2012). Applications of image processing in agriculture: A survey. International Journal of Computer Applications, 52(2): 34-40. http://dx.doi.org/10.5120/8176-1495
[35] Bakhtadze, N.N., Maksimov, E.M., Maksimova, N.E., Donchan, D.M., Kuznetsov, D.S., Zakharov, E.A. (2020). Intellectual management systems for digital farming. Informatsionnye Tekhnologii i Vychislitelnye Sistemy, 2: 85-111. https://doi.org/10.14357/20718632200208
[36] Saiz-Rubio, V., Rovira-Más, F. (2020). From smart farming towards agriculture 5.0: A review on crop data management. Agronomy, 10(2): 207. https://doi.org/10.3390/agronomy10020207
[37] European Parliament, European Commission, Directorate-General for Internal Policies of the Union, Joint Research Centre, Zarco-Tejada, P., Loudjani, P., Hubbard, N. (2014). Precision Agriculture: An Opportunity for EU Farmers – Potential Support with the Cap 2014-2020: In-Depth Analysis. European Union, Brussels. https://doi.org/10.2861/58758
[38] Kuldybayev, N., Dutbayev, Y., Lozowicka, B., Slyamova, A., Tsygankov, V. (2021). Effects of root rot in soybean cultivars with diverse susceptibility to the disease on plant physiology, yield, amino acids and mycotoxins profile in climatic conditions of Kazakhstan. OnLine Journal of Biological Sciences, 21(4): 312-321. https://doi.org/10.3844/ojbsci.2021.312.321
[39] Popova, L.V., Gorshkova, N.V., Shaldokhina, S.Yu. (2019). The introduction of agricultural techonologies 4.0: Conditions and forecasts. Vestnik AGU, ser. "Ekonomika", 1(235): 83-89.
[40] Popova, L.V., Lata, M.S., Mitrofanova, I.V. (2016). The innovative potential of small-sized enterprises in the agro-industrial complex. Economics: Yesterday, Today and Tomorrow, 9: 353-364.
[41] Laiskhanov, S.U., Poshanov, M.N., Smanov, Z.M., Karmenova, N.N., Tleubergenova, K.A., Ashimov, T.A. (2021). A study of the processes of desertification at the modern delta of the Ili River with the application of remote sensing data. Journal of Ecological Engineering, 22(3): 169-178. https://doi.org/10.12911/22998993/132546
[42] Litvinov, F.I. (2017). The sustainable socio-economic development of the agro-industrial complex during Russia's transition to the digital economy. Ekonomika i Sotsium: Sovremennye Modeli Razvitiya, 15: 91-99.
[43] Kislyakova, E.M., Achkasova, E.V., Vladykina, E.L., Berezkina, G.Yu., Bass, S.P., Azimova, G.V. (2022). Alternative sources of protein in the diets of highly productive cows. Revista Electronica De Veterinaria, 23(2): 7-13.
[44] Seifullaeva, M.E., Panasenko, S.V., Shirochenskaya, I.P., Tsvetkova, A.B., Yevseyeva, J. (2018). Main tendencies and problems of agricultural export and import in Russia under economic sanctions. Revista Espacios, 39(9): 38.
[45] Denisova, D.A., Levanova, N.G., Dibrova, Zh.N., Isakova, G.K., Hafizov, D., Lizina, O.M. (2021). Indicators of state financial support for capital reproduction in the agricultural economic sector: The European Union and Russia. Universal Journal of Agricultural Research, 9(5): 176-183. http://dx.doi.org/10.13189/ujar.2021.090504
[46] Janteliyev, D., Julamanov, T., Rsymbetov, B., Kaldybekov, A., Allaberganova, Y. (2022). Increasing the level of management efficiency: Using unmanned aerial vehicles for monitoring pasture lands. Instrumentation Mesure Métrologie, 21(2): 59-65. https://doi.org/10.18280/i2m.210204
[47] Zhanabayev, A.A., Nurgaliev, B.Y., Kereyev, A.K., Paritova, A.Y., Ussenbayev, A.Y., Bayantassova, S.M., Seitkamzina, D., Zhumagaliyeva, G.K., Yelemessova, B. (2022). Parasite Fauna and Infection of Sheep with Parasitosis. OnLine Journal of Biological Sciences 2022, 22(4): 404-414. https://doi.org/10.3844/ojbsci.2022.404.414