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AgroTech

AI, Big Data, IoT

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ISBN 978-981-19-3554-1 ISBN 978-981-19-3555-8 (eBook)
https://doi.org/10.1007/978-981-19-3555-8

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

AgroTech as a Digital Vector of Sustainable Development of the Agricultural Economy (Introduction)

At present, agricultural economics has to solve the complex and responsible task of provision of food security. The problem with the achievement of this task is that the innovative business trends of recent years were concentrated in other spheres of the economy and were only indirectly connected to the agricultural economy. Thus, in the first decade of the twenty-first century, financial innovations were actively created and implemented in the post-industrial (service) economy. After the global financial and economic crisis, the industry received a new impulse for development in the second decade of the twenty-first century. Neo-industrialisation—a new cycle of industrialisation, which implies the development of high-tech industry—took place.

The COVID-19 pandemic and crisis became a crucial moment of the modern age of the world economy's development since they started a global tendency for the diversification of the economy. Despite the undoubted destructive impact on humanity, the pandemic sent an important signal: all spheres of the economy are important and need to be developed. It became possible to implement the idea of economic diversification due to the Fourth Industrial Revolution. The transition to a new—digital—technological mode created preconditions for the modernisation of all spheres of economy. In the agricultural economy, this led to the emergence of AgroTech, which uniqueness and high theoretical and practical significance consist in its disseminating sustainable digital innovations.

AgroTech is not just high-tech agriculture—it is a new model of agriculture under the conditions of the digital economy based on the leading technologies—Artificial Intelligence (AI), Big Data and the Internet of Things (IoT). The specifics of this new model consist in the fact that agribusiness in AgroTech is based on the innovative production factors and innovative organisational and managerial solutions on the use of these factors in the production and distribution processes.

In the aspect of labour, AgroTech requires digital agricultural personnel. On the one hand, this requires serious retraining of the current agricultural personnel and causes a serious burden on the system of professional and higher education. On the other hand, this ensures the creation of highly efficient, knowledge-intensive and

well-paid jobs in the agricultural economy. The value of human resources in agriculture grows in the course of the development of AgroTech, and wider perspectives for their human potential development open.

In the aspect of the land, AgroTech does not have a clear binding to land. There is a transition from horizontal to vertical farms and from soil to hydroponics. The transition to AgroTech allows (for the first time) reducing the role of land as a production factor in agriculture—it gradually moves to the background, giving way to technology, which becomes most significant. In the aspect of capital (technologies), AgroTech is connected to the use of automatized and robotised agricultural machinery. The core of agribusiness in AgroTech is the IoT—a leading technology, which allows for continuous communication between technical devices.

In the aspect of entrepreneurial abilities and management in AgroTech, AI performs the automatized control of smart farms. AgroTech is a path to machine management of agribusiness. AI allows conducting automatized phytomonitoring—control of growth of each plant, collecting and analysing Big Data. This is a path to predictable agriculture with stable productivity.

The importance of studying and managing the development of AgroTech is explained by its ensuring the successful practical implementation of all main Sustainable Development Goals (SDGs), which are set before the modern agricultural economy. First, SDG 2 and SDG 3: AgroTech allows achieving the maximum possible quality of food and guaranteeing it. Due to the automatized phytomonitoring based on AI, Big Data and the IoT, selective quality control becomes total. The sorting of food by the criterion of quality is accelerated and simplified.

Added value chains become more transparent in the agricultural economy. Their control becomes accessible not only for government controlling bodies but also for all interested parties. In addition, the establishment of AgroTech allows for the production of food with the set and improved nutritional properties. Random (risk) component in agriculture is reduced. Labour efficiency receives new possibilities for growth, which allows the global fight against hunger.

Second, SDGs 6-8: AgroTech is a breakthrough in water supply, energetics and production organisation. Irrigation has always been a foundation stone of agriculture. One of the most important problems of irrigation is the deficit of water resources in dry territories. AgroTech allows optimising the collection, storing and spending of water resources in case of their deficit, as well as performing a precise dosed supply to each plant.

AgroTech is also "clean" energetics in agriculture. An increasing number of smart farms around the world start using renewable energy sources: sun, water and wind. It should also be noted that human resources management in AgroTech becomes more responsible due to the automatized production process. The transition from hard manual labour to intellectual activity makes high-tech agribusiness attractive for employment and career-building by young agricultural personnel.

Third, SDG 10 and SDG 11: AgroTech is a source of economic growth and development of rural territories. It is worth noting that though smart agriculture is also accessible in cities, rural territories remain the centres of the agricultural economy. Not only does AgroTech accelerate the economic growth of rural territories, but it also

strengthens their competitive advantages as environmental spaces for living, work, tourism, and business. Well-balanced development of urban and rural territories is a new reality, which is accessible due to AgroTech. Of course, it is necessary to note the inflow of investments in the development of rural territories. Agribusiness ceases to be very risky and unprofitable; instead, it quickly develops and brings large profits.

Fourth, SDG 13: AgroTech is a leading method of agriculture's adaptation to climate change. Though the fight against climate change is conducted around the world, this problem is still very urgent as of now; it probably will not be completely solved in the next decade (though, of course, substantial progress in its resolution could be expected). The agricultural economy is a sphere of the economy that suffers the most from climate change.

Climate-smart agriculture in AgroTech is a perspective answer of the agricultural economy to climate change. Smart farms feature the internal artificial climate, which is supported all year round. This makes them autonomous (independent from the external environment). The key advantages of AgroTech in this respect are the increased and multiple crop yield, as well as prevention of the ruin of the plants caused by unfavourable weather conditions.

The transition from horizontal farms to vertical farms also allows leaving natural territories untouched. This contributes to the preservation of biodiversity (SDGs 14–15). In addition to the above, AgroTech in itself is a manifestation of the successful practical implementation of SDG 9 in the agricultural economy. Other SDGs are also supported in AgroTech, which ensures its systemic contribution to sustainable development.

This book's objective is the comprehensive study of AgroTech, formation of a coherent scientific view, provision of scientific and methodological support, and preparation of applied solutions for the development of AgroTech. This objective is consistently achieved in the four parts of the book. The first part forms a scientific concept of AgroTech as a new model of agriculture under the conditions of the digital economy based on AI, Big Data and IoT. The second part contains the study and analysis of the case experience of the formation and development of AgroTech in Russia and its regions. The third part elaborates on the current problems of agriculture and the perspectives of their resolution based on AgroTech. The fourth part contains applied recommendations and frameworks for the development of AgroTech.

The originality and novelty of this book consist in the reconsideration of the scientific concept of AgroTech through the lens of sustainable development, which allows balancing high-technology and socio-environmental responsibility of the agricultural economy. The book's uniqueness consists in the in-depth multidisciplinary study of AgroTech: from the positions of economics (agribusiness), information and communication technologies (high technologies for agriculture), management, human support (pedagogics), agroecology, environmental economics and other scientific disciplines.

This book is aimed primarily at scholars who study AgroTech. In this book, they will find a coherent theoretical view of AgroTech as a multidisciplinary scientific concept and the fundamental view of the perspective of the agricultural economy's sustainable development based on AgroTech. This book could be also interesting for

the representatives of agribusiness and state regulators of the agricultural economy. Due to the in-depth elaboration of the given topical area, the book is a practical guide for agriculture's transitioning to AgroTech. The applied recommendations and frameworks of the development of AgroTech, which are proposed in the book, will be useful in practice.

Contents

AgroTech: A New Model of Agriculture Under the Conditions of the Digital Economy Based on AI, Big Data and IoT

Farm Machinery Depots in Technical and Digital Support of Agriculture

Yuliya S. Korotkikh, Yuliya V. Chutcheva, and Nikolay N. Pulyaev

Abstract Over the years of its existence, farm machinery depots in Russia allowed organizing efficient machine use and bringing the country to a high technological level in agriculture. Nevertheless, at different levels of existence, farm machinery depots tended to go bankrupt and be liquidated due to their narrow orientation. Due to the high financial burden on small and medium-sized farms, farm machinery depots can serve as a technological breakthrough. At the current level of development, farm machinery depots are provided with modern energy-saturated agricultural equipment and modern digital technologies. The development of computer technology and wide access to global positioning systems and geographic information systems led to a new concept called "precision farming" or "coordinate farming." The use of precision farming allows analyzing the planned and actual costs at each stage of crop cultivation and monitoring production costs. Uncrewed aerial vehicles are actively used in agriculture. First, it allows mapping, monitoring, and diagnostics of fields. However, such opportunities are available to large agricultural producers. To solve the problems of applying innovative technologies in agriculture for various forms of economy, the most promising solution is their interaction with farm machinery depots. Equipping farm machinery depots with innovative technologies will allow for the provision of mechanized services to agricultural producers and the loading in the full cycle of the production process using digital technologies.

Keywords Agriculture · Agricultural producers · Innovative technologies

JEL Code A10

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_1

1 Introduction

The study of the historical aspects of the operation of farm machinery depots seems interesting from a scientific and practical point of view since it has proved the possibility of organizing efficient use of machinery.

Mechanized units for the cultivation of agricultural land had different names in different years. During the period of industrialization in the USSR, it was called machine and tractor stations. With financial support from the government, these stations provided material and technical conditions for the effective use of a fleet of new agricultural machines and served as a mechanism for governmental influence on collective farms.

The accelerated growth of machine and tractor stations was facilitated by the formation of factories for the production of agricultural equipment (e.g., Rostselmash, Saratov Plant, Stalingrad Tractor Plant, Kharkiv Tractor Plant, Chelyabinsk Tractor Plant, and others), which allowed the country to form a powerful technical base for agricultural production (Korotkikh et al., 2021).

Despite such an intensive pace of technical equipment and the large-scale development of virgin lands implemented during this period, the country's food supply problems were not solved completely. The reason for this was an incorrectly built motivational policy. The collective farm paid for the work performed, which was estimated by hectares of soft plowing and not by the yield of crops (Chutcheva et al., 2020). This fact led to the liquidation of machine and tractor stations by the beginning of the 1960s. The equipment owned by the machine and tractor stations was transferred to the collective farms, and the repair functions were assigned to the new public structure of "Soyuzselkhoztehnika."

As a result of these changes, large and highly developed collective farms were strengthened in the country. The material and technical base of these farms has been strengthened by the equipment received. Moreover, based on the results of the activities, these farms managed to update the machine and tractor fleet promptly, while small agricultural organizations failed in their activities, and the equipment quickly failed. The costs for repair and maintenance were high, which did not further contribute to the effective development of small-scale production (Revkutz et al., 2019).

The revival of farm machinery depots occurred at the end of the 1990s after adopting the Decree of the President of the Russian Federation "On measures for the development of the network of farm machinery depots for servicing agricultural producers." During these years, the number of farm machinery depots reached 500 units and continued to grow until the mid-2000s (Chutcheva et al., 2020).

In the mid-2000s, there were more than 900 farm machinery depots (FMDs) in the Russian Federation; they performed up to 6% of all fieldwork. However, their activities were accompanied by significant difficulties. Nowadays, the number of FMDs has decreased. The main reasons for this reduction are as follows:

- Inadequate uptake of high-intensity technologies;
- Lack of tax incentives in the current legislation for FMDs since they are not agricultural producers;
- Haste and lack of justification for the ongoing economic reforms of the agro-industrial complex;
- Low solvency of agricultural producers;
- High costs of credit resources.

The largest share of consumers of the services provided by FMDs was in financially unstable farms, which, upon completion of work by FMDs, were not able to pay for the work performed by them in a timely and complete manner. This fact caused an increase in the cost of services rendered by FMDs and, consequently, the disruption of the very system of service and settlement in the industry (Belyakov & Rizhaya, 2019).

Simultaneously, the positive experience of FMDs is well known in the Belgorod, Voronezh, Tula, and Oryol Regions, as well as in the Republics of Bashkortostan and Tatarstan. For example, in the Voronezh Region, Pavlovskaya MTS was created based on repair and technical organizations. It overhauls tractors and creates an exchange fund for repaired machines. When tractors break down and cannot be repaired by the own forces of agricultural producers, they transfer such machinery to the FMD. In turn, the FMD gives agricultural producers a repaired machine from the exchange fund for the time of repair. Thus, agricultural producers can hire equipment for the duration of its repair or purchase restored equipment from the exchange fund at a reduced price. According to the same method, the Tula Region restores harvesters. In the Republic of Bashkortostan, all types of agricultural equipment are restored using this method (Vorozheykina & Bobovnikova, 2021).

During this research, the authors studied the practical experience of the functioning of Central MTS, which was created in the 1990s and currently operates in the Republic of Bashkortostan. Central MTS aims to provide mechanized services in the field of crop production. Currently, it is one of the few FMDs in Russia that provides mechanized services to agricultural producers specializing in the production of crop products, as well as services for the restoration of agricultural machinery and sale of restored equipment. Currently, Central MTS has its own agricultural lands. At the initial stage of its development, the equipment was purchased at the expense of the national budget, which allowed the Republic of Bashkortostan to significantly support its agricultural producers and increase the efficiency of agricultural production with the help of the FMD. Central MTS is currently fully self-sufficient. It rented more than 300 thousand hectares of arable land in the Republic of Bashkortostan for cultivating crops of its own production. Currently, there are more than thirty branches in all soil and climatic zones of the Republic of Bashkortostan, three specialized repair shops, five grain elevators and bread receiving points, two feed mills, and service stations for the maintenance of equipment (Belyakov & Rizhaya, 2019).

The FMD of the Republic of Bashkortostan, on average, cultivates about 30% of the sown areas under grain. For some areas, this figure reaches 90%.

During the research, the authors also studied the experience of FMDs in the Republic of Tatarstan. The productivity of FMDs of the Republic of Tatarstan is 1.7 times higher, and the cost price is 1.1–1.2 times less than in agricultural organizations. The cost per ton of forage and milled grain harvested by FMDs is two times lower than in the farms of the Republic of Tatarstan (Chutcheva et al., 2020).

2 Materials and Methods

The authors analyzed the existing farm machinery depots in 18 subjects of the Central Federal Districts of the Russian Federation. According to the research results, eight subjects of the Central Federal District (Ivanovo, Kaluga, Lipetsk, Moscow, Smolensk, Tver, and Yaroslavl Regions, and the city of Moscow) either do not possess operating FMDs or these FMDs are in the elimination stage. In three subjects of the Central Federal District (Belgorod, Tambov, and Tula Regions), the operating FMDs specialize in installing, repairing, and maintaining agricultural machinery. In two subjects of the Central Federal District (Kostroma and Kursk Regions), the FMDs are engaged in producing grain and leguminous crops and forage crops and preparation of vegetable forages. Farm machinery depots render the mechanized services at the crop production in five subjects of the Central Federal District (Bryansk, Voronezh, Oryol, Ryazan, and Vladimir Regions) (Vorozheykina & Bobovnikova, 2021). In the five last subjects of the Central Federal District, the FMDs are registered as municipal unitary enterprises, allowing them to receive funding from budgetary funds.

While analyzing historical factors of the existence of farm machinery depots in the territory of Russia, the authors marked out that FMDs with the state form of ownership had a positive functional dynamic, in contrast to privately owned FMDs. The founder of government regulation, J. M. Keynes, argued that government spending was the main means of reviving the economy. He supported direct governmental control of the development of agriculture and the food market. The role of the government was also confirmed by L. Erhard, the minister of the national economy of Germany in 1949–1963. He confirmed the special role of the government during the depression (Korotkikh et al., 2021).

The analysis, which the authors carried out earlier, allowed them to define one of the most significant reasons for the low efficiency of FMDs—the narrow range of services. Therefore, in the Voronezh and Tula regions and the Republics of Chuvashia and Tatarstan, the FMDs performed only the functions of technical repair organizations, carrying out capital repairs of tractors and combine harvesters (Chutcheva et al., 2020).

Since the main customers of FMDs are agricultural producers, the majority of which are marked with financial instability and low solvency, they cannot timely pay FMDs for the services rendered. Thus, accumulating accounts receivable, followed by accounts payable, FMDs have a low level of profitability of their activities.

According to A. A. Zangiyev, A. N. Katelikov, E. O. Knyazeva, L. I. Kushnarev, A. V. Larionov, and T. A. Tiranova, higher efficiency of functioning of FMDs can be reached in the conditions of the organization of a complete cycle of production of agricultural products and effectively functioning technical service (Korotkikh et al., 2021).

Agreeing with the cited researchers, the authors believe that a significant role in the efficiency of FMDs is played by the application of technical and technological innovations and the provision of highly qualified personnel (e.g., experts in agriculture and technical support).

However, it is proposed to transfer the function of maintenance and repair of equipment to large repair or dealer centers by entering into long-term contracts on client service.

Additionally, to increase the efficiency of activity of FMDs, the authors propose to create multipurpose FMDs, which, in addition to their primary activity (performance of the mechanized works for agricultural producers), will work in close interrelation with selection stations, dealer and information advice centers, educational institutions (institutions of higher education and institutions of vocational training), and the centers of preparation or retraining of experts.

Thus, the authors consider it reasonable to create FMDs as multidisciplinary organizations focused on the provision of services for the production of agricultural products using high-performance equipment and high-tech technologies, which will allow increasing the loading of the equipment, increasing the appeal of work in agriculture, reducing harmful effects on the environment when performing the mechanized works, increasing the quality and volume of production, and reducing losses during harvesting.

Besides, the authors propose the specified structure of FMDs with the expanded functional purpose of their activities. Having analyzed the works dealing with the efficiency of FMDs, the authors defined some discrepancies with the modern requirements imposed on FMDs.

3 Results

The authors agree with some of the analyzed definitions of FMDs formed by Russian scholars (D. S. Aleksanov, E. Z. Asadullin, B. B. Basaev, N. T. Batyrova, I. A. Piskacheva, A. N. Katelikov, and L. N. Tsedashiev) (Korotkikh et al., 2021). Nevertheless, the authors have previously identified the factors causing the inefficiency of FMDs in various regions. One of these factors is the narrow focus of FMDs.

The main conceptual aspects of the functioning of FMDs allowed the authors to clarify their essence.

Thus, the authors propose their own clarification of the essence of FMDs. A farm machine depo is a multifunctional information and technical platform that carries out joint production of raw materials and products with agricultural producers, interacting with organizational structures directly or indirectly involved in producing

agricultural raw materials and products. The unification of such organizational structures aims to achieve high-tech, scientific, educational, organizational, and economic results to increase the efficiency of agricultural production and solve food security issues in the country.

Digitalization can increase the productivity of production processes by controlling the execution of technological operations. Additionally, such systems allow accelerating internal document flow within organizations.

The data received from various devices located in the field, farms, equipment, drones, and satellites allows obtaining up-to-date information and making timely decisions using modern methods of processing data in large volumes, which is used to make decisions that can minimize risks and improve the production and sale of agricultural products.

Digital agriculture allows determining the optimal time for planting seeds, selecting the most suitable fertilizers and optimal harvest times, calculating the time for loading and delivering cargo to the buyer, monitoring the temperature in the storage and transportation zone to reduce losses, and predicting crops and income (Chutcheva et al., 2020).

On an industrial scale, these technologies are available to large agricultural holdings that solve narrow point problems within a single enterprise. The introduction of such technologies in each agricultural producer is impossible due to the lack of free money, low solvency, and the lack of qualified personnel. It is impossible and irrational to have a specialist in computer processing and analysis of spatial information in each farm. Additionally, it is advisable to assess and analyze agricultural land in a complex throughout the region, ensuring the accuracy and completeness of the data obtained. Simultaneously, the cost of obtaining and processing data will be distributed among many farms, which will reduce their costs in this area and further contribute to the increase in the economic efficiency of agricultural production.

4 Discussion

Currently, agriculture in the developed countries uses powerful agricultural machinery, advanced agronomic methods, and modern computer technologies that increase production efficiency, improve yield and quality of products, lower production costs, and reduce losses in the production process (Korotkikh & Chutcheva, 2021).

Meeting these challenges requires a considerable amount of input data, which is most feasible when using information technology in agriculture since there is a need to collect and maintain information databases on a large number of agricultural lands over a long period (Chutcheva et al., 2020).

5 Conclusion

To solve the problems of applying innovative technologies in agriculture at the regional level and introduce digitalization in medium and small farms, the most promising solution is interaction with FMDs. Equipping FMDs with innovative technologies will allow providing mechanized services to agricultural producers and ensuring loading according to the full cycle of the production process using digital technologies, which will be aimed at improving the quality of products produced and increasing the efficiency of resources use.

The authors suggest using geographic information systems in FMDs, which would be able to collect data from the entire region, process the results, and provide advisory services to agricultural producers.

Only the relevance, accuracy, and completeness of initial data can ensure the effective use of information technologies in agriculture.

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Directions for Stimulating Digitalization in the Agricultural Sector of the Russian Economy

Elena V. Plotnikova, Alexander A. Mokrushin, Karina S. Prikhodko, Natalia A. Asanova, and Saniyat Y. Hut

Abstract Currently, digital transformation is one of the main priorities of the development of the Russian agricultural sector because the level of digitalization characterizes the competitiveness of the industry in the new technological order and contributes to the prospects of innovation breakthrough. This fact determines the relevance of the research. The paper aims to develop proposals for solving problems hindering the digitalization of the agricultural sector. The authors apply the methods of monographic and economic-statistical analysis and the results of theoretical and practical research of the authors of thematic publications. The analysis of the indicators of digitalization of agriculture showed that its pace is insufficient. The evaluation of the results of the expert survey and the review of a set of information-analytical sources allowed us to identify the problems hindering the digitalization of the agricultural sector. The main problems include the lack of financial resources of the majority of agricultural producers to implement digital technologies, their low level of awareness of the benefits of digitalization, and the shortage of IT specialists in the agricultural sector. To solve the identified problems, the authors propose to form a system of incentive measures of government support, create a system of education and training of specialists of agricultural organizations to form their digital competencies, and organize information and awareness-raising work in the field of digitalization. To implement these proposals, it is advisable to create a network of regional centers of competence. The effect of implementing the proposed system of measures will be expressed in the achievement of the target indicators of the federal project "Digital

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_2

Agriculture," including the growth of labor productivity and reducing the share of material costs in the cost of agricultural products.

Keywords Digital transformation · Digital agriculture · Digitalization index · Government support · Agricultural producers

JEL Codes H7 · Q1 · Q18

1 Introduction

Digital transformation has significant potential in the innovative technological development of the agricultural sector. It is one of the main trends in its development in the near future. In the current conditions, the organization of highly profitable and competitive agricultural production involves its digitalization, which contributes to improving the efficiency of management and production processes. According to the forecasts of the Ministry of Agriculture of the Russian Federation, the Russian market of digital agricultural technologies, which amounted to about 360 billion rubles in 2019, should grow by five times by 2026 (Sandu et al., 2018; Trukhachev et al., 2020).

However, Russia currently ranks 15th in the world regarding the digitalization of agriculture. The Russian agricultural sector significantly lags behind Europe and the USA in the level of implementation of digital solutions: three times compared to Germany and France and four times compared to the USA. According to various estimates, digital technology is implemented in no more than 10–15% of Russian farms, while in the USA and Europe, this figure is 60–80% (Kulistikova, 2021; Ogorodnikova & Singaeva, 2020; Ushachev et al., 2019).

Thus, in the current conditions, the development of proposals to create conditions for a more active implementation and use of digital solutions in the agricultural entities of all forms of economic management is highly relevant.

2 Materials and Methods

The research aims to identify the main areas of solutions to the problems hindering the active digitalization of agriculture. The research aim led to the formulation and solution of the following interrelated tasks:

- To analyze and evaluate the indicators of digital development of agriculture;
- To formulate the main problems hindering the development of digitalization in the agricultural sector of the economy;
- To justify the primary directions of stimulating the innovative development of agricultural organizations based on the introduction and use of digital technologies.

The theoretical and methodological basis of the research included fundamental and applied works of Russian and foreign scholars in the field of digitalization of the agro-industrial complex, expert studies, and thematic publications in the periodical press. The specifics of the studied object and the set tasks determined the use of such research methods as monographic, analytical, economic-statistical, expert assessments, abstract-logical, and others.

3 Results

The need to apply digital technologies in the agricultural sector is due to its features such as:

- Dependence of the production process on a set of factors (natural and climatic, soil, biological, economic, and social), most of which are variable in time and space, and the combination of the economic reproduction process with the natural processes;
- Territorial dispersion of agricultural production leading to a significant complexity of management decisions;
- Complex of intersectoral interaction of agricultural producers with processing organizations, suppliers of resources, and buyers of products (Ministry of Agriculture of the Russian Federation, 2019a; Trukhachev et al., 2020).

To assess the level of digital development of agriculture, the authors analyzed the main indicators in this area compared to the average level of similar indicators of other sectors of the Russian economy, which are part of the entrepreneurial sector—industry, construction, trade and catering, and transport (see Appendix 1).

According to the analysis of the data in Table A.1, agriculture is marked with a lower level of use of digital technology compared to the sectors of the business sector, which is reflected in a significant lag in the totality of the presented indicators. A comprehensive indicator of digitalization, developed by the Institute for Statistical Studies and Economics of Knowledge (ISSEK HSE), is the digitalization index, which is calculated as the arithmetic average of the proportion of organizations (in the total number of organizations in segments of the economy) that use the appropriate types of digital technology. In agriculture, this indicator equaled 23 conventional units (24—in livestock and 21—in crop production), while in the economy as a whole, it was 29, in the business sector—32 (Abdrakhmanova et al., 2021). Thus, Russian agriculture is one of the most technologically conservative industries. It is marked with a low level of innovative development and a slow pace of digitalization compared to the same processes in other areas of the Russian economy and foreign agricultural practice.

To assess the problems and prospects of the development of digital technologies in the agricultural sector, the Center for Forecasting and Monitoring in the field of precision agriculture, automation, and robotics of Kuban State Agrarian University conducted a survey and interviewed experts representing scientific and educational

communities, business, and government authorities from 16 regions of Russia (see Appendix 2).

According to the survey, 33% of managers of Russian agricultural organizations are reticent about digital solutions because of the lack of information about the possibilities of digitalization; the same number is not satisfied with the high cost of digital technology. The respondents identify the following problems hindering the digital development of agriculture in the Russian Federation (Trufliak et al., 2017):

- 32% of respondents indicated the lack of government support;
- 25% believe that there are currently almost no Russian digital solutions on the market;
- 22% see the shortage of qualified specialists as an obstacle.

The evaluation of the examination results and review of a set of information-analytical sources allowed the authors to identify the main problems hindering the development of digitalization in the agricultural sector and determine the directions of their solutions (Fig. 1).

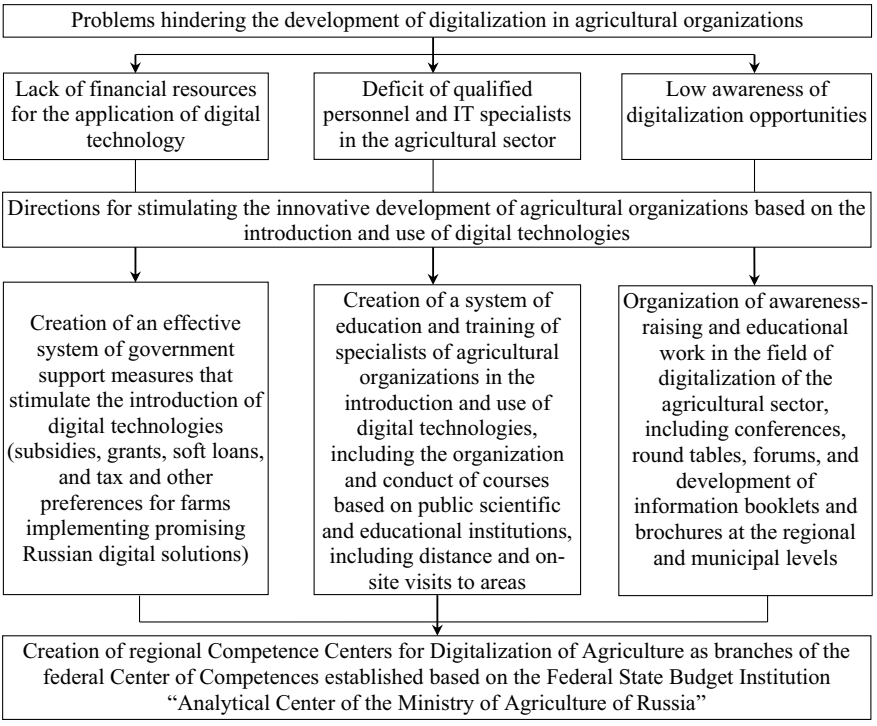

Fig. 1 Problems in the development of digitalization in agricultural organizations and their solutions. *Source* Compiled by the authors

4 Discussion

Let us consider the content of the presented problems and the directions of their solution.

4.1 Lack of Financial Resources for the Implementation of Digital Technology in Most Agricultural Producers

The level of digitalization of the agricultural sector of Russia is heterogeneous and reflects its multi-layered nature. As a rule, large export-oriented agricultural holdings have a very high level of digitalization, even on a global scale. In a competitive global market, a high level of technological modernization is required; digital technology allows the company to effectively solve problems of production, processing, and studying marketing preferences and product delivery. On the other hand, small and medium agribusinesses cannot afford the large-scale application of digital technology. For most farms, the costs and associated risks are high. However, the introduction of digital technology is relevant to any farm, regardless of the business scale, because it allows minimizing production risks, optimizing production costs, and improving the profitability of agricultural production and competitiveness of agricultural products (Sandu et al., 2018; Voronina, 2020).

In this situation, government support plays an essential role because agricultural producers are not always aware of the economic effect of the introduction of digital technologies, the cost of which is quite high. Therefore, there is a low level of willingness to implement innovations. To solve this problem, it is advisable to develop a system of government support stimulating the introduction of digital technologies, including subsidies, grants, soft loans, and tax and other preferences to agricultural farms that implement promising Russian developments. For this system of measures to be effective and efficient, it is necessary to constantly identify and analyze point problems hindering the development of agricultural digitalization. Moreover, it is necessary to identify the most promising (from the perspective of agricultural producers) digital solutions and products.

Currently, federal support for introducing innovation in the agricultural sector is insufficient; regional support measures are not implemented in all Russian regions (see Appendix 3).

Support measures are also implemented in the Belgorod, Nizhny Novgorod, Novosibirsk, Smolensk, Tambov, Tver, Tyumen, and Yaroslavl Regions, as well as in the Khabarovsk Territory (Trufliak, 2020).

4.2 *Deficit of Qualified Personnel and IT Specialists in the Agricultural Sector*

In general, Russia has a low level of digital literacy compared to European countries. According to the Analytical Center of the Ministry of Agriculture of the Russian Federation, there is about one IT specialist per 1000 people employed in agriculture. However, the implementation of digital solutions requires qualified full-time employees or support from developers. In this regard, there is a need to hire specialists with the necessary qualifications or train employees to work with new technologies. The training of employees of an agricultural organization is a crucial condition for the successful implementation of innovative projects.

To solve this problem, it is advisable to create a system of education and training of specialists in the agricultural sector to form their knowledge and skills in working with digital equipment, including the organization and conduct of short-term courses in the field of digitalization of agribusiness based on scientific and educational institutions. It is also necessary to provide distance and on-site courses in rural areas. As part of the implementation of the Russian project "Digital Agriculture," continuous training of specialists of agricultural organizations is planned based on the Competence Center "Digital Agriculture" with offices in agricultural universities of the Ministry of Agriculture of Russia. To this end, an electronic educational industry environment, "Land of Knowledge," is created, which will allow distance learning for specialists (Ministry of Agriculture of the Russian Federation, 2019b; Skvortsov et al., 2018).

4.3 *Low Awareness of Digitalization Opportunities Among Agricultural Producers*

As a rule, agricultural producers are so immersed in their current work that they often do not know how digital technology works, how the process of its implementation occurs, and, most importantly, what economic effects their use can provide. In this regard, it is necessary to organize the awareness-raising and educational work in digitalization at the municipal level. Agricultural managers should be well aware of the benefits of digital technology. To this end, it is advisable to hold scientific and practical conferences, seminars, forums, and roundtables at the regional and municipal levels of government to familiarize agricultural producers with the latest developments in the digitalization of the agricultural sector. Additionally, it is necessary to develop advertising and information brochures and booklets in this area.

The problems hampering the development of agricultural digitalization also include the following:

1. Underdevelopment of digital infrastructure—weak telecommunications, including the lack of advanced high-quality cellular communication and the Internet in some farms and remote agricultural areas, which hinders the work of,

for example, field monitoring programs and related modules and causes difficulties with the collection, processing, and transmission of data. The introduction of digital technology requires full coverage of rural areas with high-speed data networks (Akhmetov & Galikeev, 2019; Ministry of Agriculture of the Russian Federation, 2019a).

2. Insufficient number of Russian scientific developments and patents in the sphere of agricultural digitalization. However, it should be noted that since 2018, when agriculture was included in the list of industries to be digitally transformed, a large number of high-quality Russian IT solutions have appeared that compete with foreign ones. Additionally, Russia has the potential for leadership in several technological areas. For example, in terms of introducing AI systems, the Russian school is one of the best in the world (Voronina, 2020).

To implement the proposed directions to stimulate the digital transformation of the agricultural sector, it is advisable to create a network of regional competence centers for digitalization of agriculture, acting as branches of the federal Competence Center established on the basis of the Federal State Budgetary Institution "Analytical Center of the Ministry of Agriculture of Russia." The practice of creating such centers already exists in some regions of Russia. For example, the Altai State Agrarian University established the Center of Competence for Digital Agriculture, whose main tasks are to test the activities of the departmental project "Digital Agriculture," train highly qualified personnel to work with digital technologies, develop algorithms for digital platform services, consult agricultural producers, and provide advanced training of agricultural workers in remote sensing and geoinformatics. A Center of Competence for training specialists in the field of the digital economy was created on the basis of the Kemerovo State Agricultural Institute. A competence center was created in Tambov, which implements a project to create a digital agricultural platform (Ministry of Agriculture of the Russian Federation, 2019a, 2019b; Trufliak, 2020).

The effect of the proposed system of measures will be expressed in the achievement of the target indicators of the project "Digital Agriculture" (see Appendix 4).

As can be seen from Table A.4, the main indicators of improving the efficiency of agricultural organizations as a result of the introduction of digital agricultural technologies and increased investment in innovative digital development are the increase in labor productivity by two times per employee and reducing the share of material costs in the cost of agricultural products by more than 20%. The expected result of creating a system of continuous training is the acquisition of the necessary knowledge and skills in the digital economy by at least 50% of the specialists employed in the agricultural sector of the economy.

5 Conclusion

The research identified the acute problems hindering the active digitalization of agriculture and developed proposals for the solutions of these problems to improve the level of innovation development of the industry. Thus, the goal and objectives set in the scientific work were achieved. The practical significance of the research lies in the possibility of using the recommendations by public authorities and local governments to improve the efficiency of the system of regulation of innovation development of agricultural organizations based on the use of digital technologies and enhancing the industry's competitiveness and profitability.

Appendix

Expanded data on the digitalization of the agricultural sector in the Russian Federation are presented in the data network developed by the authors (https://doi.org/10.6084/m9.figshare.17179136.v1).

Appendix 1

Indicators of digitalization in the agricultural sector of the Russian Federation, 2019 (see Table A.1).

Table A.1 Indicators of digitalization in the agricultural sector of the Russian Federation, 2019

Indicator	Agriculture	Business sector
The share of organizations that use (%)		
– broadband Internet (%)	74.3	86.0
– cloud services (%)	20.9	29.1
– websites	25.1	48.5
– software tools to solve organizational, managerial, and economic tasks	41.8	57.2
– electronic sales	8.3	14.6
– electronic procurement	14.3	20.1
– RFID technology (auto-identification of objects)	5.5	8.2
– ERP systems (enterprise resource planning)	5.5	23.3
– CRM systems (customer relationship management)	3.6	18.6
– SCM systems (management of relationships with suppliers and customers)	2.1	10.6
Employees of organizations using the Internet (%)	13.5	31.5
Share of organizations' expenditures on the implementation of digital technologies and related products and services (%)		
– in the total expenditures of organizations for these purposes	0.6	66.1
– in the gross value added of the industry	0.4	2.2
Share of organizations' expenditures on the purchase of Russian software, its adaptation, and its improvement in the total volume of costs for its acquisition %	48.4	60.0
Digitalization index	23	32

Source Compiled by the authors based on [1]

Appendix 2

Results of a survey of experts on the digitalization of agriculture (see Table A.2).

Table A.2 Results of a survey of experts on the digitalization of agriculture (fragment)

Questions and answer options	Share of expert responses (%)
The main reasons for the reticence of managers and specialists of agricultural organizations to digital agricultural technology	
– Lack of information about the benefits of digital technology	33
– High hardware costs	33
– Doubts about the reliability and functionality of equipment and technology	15
– Significant time costs for mastering new technologies, professional development, and retraining costs	9
– Insufficient compatibility of technology	8
– Concerns related to the unauthorized use of computer databases	2
The main problems in the development of digital agricultural technologies in the Russian Federation	
– Lack of government programs, coordination, and support for their development	32
– Russian industry is practically not engaged in the production of digital agricultural technologies	25
– Lack of qualified specialists in this field	22
– Significant initial implementation costs	11
– Lack of interest on the part of agricultural producers	10

Source Compiled by the authors based on [2]

Appendix 3

Incentive measures to support and implement digital agricultural technologies in Russian regions (see Table A.3).

Table A.3 Incentive measures to support and implement digital agricultural technologies in Russian regions (fragment)

Subject of Russia	Incentive measure of regional support
Arkhangelsk Region	Subsidy of up to 40% of the cost for the purchase of agricultural machinery that can be used in differentiated technologies of seeding, tillage, fertilizer application, and weed spraying
Kostroma Region	Subsidy in the amount of 10%–40% of the cost for the purchase of innovative agricultural machinery and equipment
Moscow Region	Subsidy in the amount of 50% of the cost for the purchase of climate control equipment, automatic herd management systems, and robotic milking systems
Ryazan Region	Subsidy in the amount of 20% of the cost for the purchase of precision farming systems (e.g., satellite navigation systems, systems of parallel driving and autopiloting, on-board sensors for precise application of fertilizers, crop monitoring, and measuring soil properties)

Source Compiled by the authors based on [3]

Appendix 4

Effect of the proposals to stimulate the digital transformation of the agricultural sector of the economy (see Table A.4).

Table A.4 Effect of the proposals to stimulate the digital transformation of the agricultural sector of the economy

Target indicator	Base value, 2018	Target value, 2024
Share of investments of agricultural organizations for the purchase and implementation of digital technologies and products in the total volume of investments (%)	0.5	25
– Including the technologies produced in Russia	0.1	20
Growth rate of labor productivity of agricultural organizations that have implemented and use digital agricultural solutions (%)	–	200
Share of material costs (e.g., fuel and lubricants, fertilizers, electricity, planting material, fodder, etc.) in the unit cost of agricultural products (%)	65	43
Share of specialists of agricultural organizations who have been retrained and have competencies in working with digital products and technologies (%)	–	50

Source Compiled by the authors based on [4]

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Agroecology in the Context of Sustainable Development: Improving the Environmental Information System

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Abstract The article examines agro-ecological activities that combine the objectives of agricultural production with maximum consideration of environmental protection and rational use of natural resources. An appropriate statistical indicator improves the recording of the process and the main results of this integrated activity. The methodology for the formation of statistical indicators presented in the article is based on international classifications used in the field of environmental protection. The main international standards applied in the field of environmental protection, conservation, use of land resources and land use are the international classifications developed by Eurostat, the UN Economic Commission for Europe, OECD, as well as the Food and Agriculture Organization. In the paper, indicators related to the accounting and statistical reflection of the role of agriculture and rural areas in preserving biodiversity, greenhouse gas emissions from agricultural production and rural areas, environmental services, and the production of raw materials for biofuel are proposed from the standpoint of an integrated analytical and informational approach. The result of the study is the creation of a system of statistical indicators contributing to the improvement of the Environmental Information System in terms of the state and development of agroecology. The agro-environmental indicators obtained are harmonized with the basic principles for the development of environment statistics in the context of sustainable development goals and can be used by the statistical services of the CIS countries.

Keywords Sustainable development · Statistical indicator · Agroecological indicators · Green economy · International classifications

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_3

JEL Codes F01 · F64 · O13 · O44 · Q20

1 Introduction

Various crises around the world have recently shown instability. It is due to the fact that all countries aspire to sustained economic growth despite the deterioration of the social and environmental situation. The concept of sustainable development emerged in the 80s which presupposed development that meets the requirements of the modern generation without affecting the vital interests of future generations (Global strategy to improve agricultural & rural statistics, 2010). This definition was proposed by the UN Commission under the leadership of G.H. Brundlandtd in 1987 (Our Common Future: Report of the World Commission on Environment and Development, 1989).

Today, sustainable development is becoming the main concept for the future. This is considered in the UN, where the main decisions and recommendations are made on a global scale. For example, the "2030 Agenda for Sustainable Development" was adopted, including the UN Sustainable Development Goals for the period 2015–2030 (Global strategy to improve agricultural & rural statistics, 2010).

The transition to sustainable development is due to the emergence of a disproportion between technological development and the deterioration of the ecological state of the territories. The growth of world GDP (fourfold) over the last period affected the quality and standard of living of the population, but at the same time, it led to the degradation of ecosystems and the depletion of natural capital. This resulted in climate change, freshwater shortages, desertification, and a decline in forests and biodiversity.

If the exploitation of natural capital remains at the same level, then the volume of emissions into the atmosphere and other negative phenomena will increase several times. This will lead to sad consequences for all of humanity.

An increase in production due to the harsh exploitation of the environment and the depletion of ecological resources does not imply sustainable development in the future. Currently, new economic models that affect the environmental sphere have become widespread. These include a low carbon economy, green economy, bioeconomy, blue economy, green growth economy and others. However, it should be noted that all of the listed models ultimately refer to a green economy.

At present, agriculture is approached in two ways, on the one hand, it is a food producer, on the other, a source of environmental pollution and land depletion (Global strategy to improve agricultural & rural statistics, 2010).

Agricultural activities, as well as the use of rural land for crop and livestock production, taking into account the requirements of ecology and rational environmental management, is called agroecology (Morjera et al., 2015).

Agroecology covers a large number of issues, such as the impact of agricultural production on the conservation of biodiversity, the volume of greenhouse gas emissions, the absorption of these gases in crop production, the state of the environment

when using mineral fertilizers and various chemicals, changes in vegetation cover, including forestry, and much more (Shepelev, 2016).

To monitor the process of transition to a green economy both in the world and in Russia, it is necessary to monitor the system of indicators. Simultaneously, the system of sustainable development goals should be evaluated and a group of statistical indicators for each goal should be developed. The existing indicators currently cannot assess the current crisis and the ways out of it, including sustainable development. Therefore, it is necessary to apply new approaches to the assessment and measurement of economic progress.

The main distinguishing feature of the new economy is the possibility of taking into account natural resources when making economic development decisions. As a result, it is necessary to improve the level of assessment of natural resources and services in methodological terms and practical activities.

2 Methodology

International classifications were used and analyzed as a methodological basis of this paper.

In 2012, the UN Statistical Commission approved the Classification of Environmental and Environmental Activities, CEA-2012 (CEA, 2012). This document is an extended version of the Classification of activities and costs for environmental protection, i.e. CEPA-2000 (CEPA, 2000), which was created by Eurostat and, in principle, approved by the UN Statistical Commission.

CEA-2012 is not based on an industry principle, but on the directions (so-called "domains", i.e. classes) of environmental, nature-saving and nature-restoring activities, combined into two fundamental groups—I. "Environmental protection" and II. "Resource management". In the first group, which is practically unchanged CEPA-2000, there are nine specified classes-directions, and in the second, fundamentally new part—six classes-directions. The CEA-2012 contains sufficiently detailed descriptions reflecting the specific composition of the relevant subdirectories and measures of environmental, nature-saving and nature-restoring activities.

In addition to the above-described CEA -2012, two classifications of soil and land resources were also included in the composition of the international standard "Central (basic) basis of the System of Natural and Economic Accounting, SEEA" in the 2012 version (System of Environmental-Economic Accounting—Central Framework-2012, 2014):

(1) Land Cover Classification System (Di Gregorio, 2005);
(2) Basic rules and classification approach for land cover (System of Environmental-Economic Accounting—Central Framework-2012, 2014).

The Central (Basic) Framework of the SEEA notes that the proposed classifications were based on the FAO materials in the form of an international standardized system called Land Cover Classification System, version 3, LARC 3 (2009).

This document can be used when organizing systematic observations (counts) of biophysical characteristics of all land areas within any territory.

When identifying the essence of agro-ecology in general and constructing appropriate indicators, in particular, it is necessary to use the recommendations of various international organizations. In this regard, the analysis of the following international organizational and methodological materials was carried out:

1. The system of statistical indicators of "green" growth prepared and approved by the OECD in 2014, supplemented in 2017 (Agriculture and Environment in EU-15, 2005; Green Growth Indicators, 2014, 2017; System of Environmental-Economic Accounting—Central Framework-2012, 2014);
2. "Agri-environmental indicators developed and adopted by the European Commission and Eurostat in 2011: recommendations for the collection of priority information and data processing" (Agri-environmental indicators: recommendations for priority data collection and data combination, 2011; Agriculture, forestry and fishery statistics, 2015);
3. "Central basis of the System of Natural and Economic Accounting" which was adopted by the UN Statistical Commission as an international standard (CO SEU)—2012 in 2012 (System of Environmental-Economic Accounting—Central Framework-2012, 2014);
4. "Basic Principles for the Development of Environment Statistics" approved by the UN Statistical Commission in 2013 (Framework for the Development of Environment Statistics, 2017;
5. The Sustainable Development Goals (SDGs) (Declaration of Rio de Janeiro on Environment and Development, 1992; Sustainable Development Goals, 2015; UN Statistics Division) were approved by the UN General Assembly in 2015.

The above classification constructions were subjected to detailed analysis in order to identify positions that have an unambiguously a very high environmental (nature-saving, nature-restoring) significance. In addition, information resources on agroecology and agroecological accounting (FAO; Federal Statistics Service of the Russian Federation; OECD; Review of selected indicators not covered by the guidelines, 2012; Statistical Office of the European Communities; Step-by-Step Monitoring Methodology for Indicator 6.4.1, 2017; UN Statistics Division) were studied. The findings were used to construct agroecological indicators.

3 Results

The system of characteristics (indicators) of the SDGs is considered the most voluminous and broadly encompassing set of indicators, which are grouped according to specific goals and objectives (Agriculture, forestry and fishery statistics, 2015). Many countries are currently guided by this System, in an adapted form and one form or another. It contains both indicators reflecting the impact on nature, showing

the effectiveness of environmental protection measures, and indicators having an economic, social and demographic orientation.

However, the actual and full-scale implementation of this System is hindered by some problems. One of them is the insufficient methodological and organizational study of issues related to obtaining reliable statistical information on many indicators.

For example, out of 244 SDG indicators in Russia, only 69 indicators are calculated and collected (i.e. 28%). There are 19 indicators at the development level, i.e. 7% of the total number of indicators. These indicators are yet not calculated, and the possibility of their implementation can only be in the future. The work on the formation of 156 indicators (64%) has not even begun. Moreover, the lowest level of development of SDG indicators is in the field of nature management, environmental impact and environmental protection (Federal Statistics Service of the Russian Federation).

SDG indicators are not being developed for Goal 13 "Combating climate change" which has 13 indicators (missing 100%). Only one indicator out of 10 (10%) has been developed for Goal 14 "Conservation of marine ecosystems" and information is being collected on it. In addition, work is underway to collect statistical data on one more indicator (10%). Still, no work is being done on the remaining 8 indicators (80%) (Federal Statistics Service of the Russian Federation).

The basic materials for the study are the documentation disclosing the Sustainable Development Goals (SDGs), developed in the UN system and some other bodies. First of all, the indicators contained in the SDGs and corresponding (or very close) to the concepts of agroecological statistics were purposefully selected, comprehensively studied and creatively used. At the same time, all the most important international standards, recommendations and other relevant documents on which this study is based were analyzed in detail, their real applied significance for statistics in the CIS countries was assessed in the field of specific categories, definitions, indicators and proposals, after which it was the selection of the most positive, promising and rather simple elements in terms of organization and information has been made.

As a result, the following system of indicators for agroecological statistics is proposed within the framework of the SDG goals.

Goal 2—Eliminate hunger, food security and improve nutrition.

Target 2.4, indicator 2.4.1. As part of the subgroup of agroecological indicators characterizing land and soil resources, it is proposed to use the following additional indicators:

(1) the area which was previously outdated as agricultural land has been newly turned around by means of cultural, technical and reclamation work (ha) for any period and/or as a percentage of the total area of agricultural land;
(2) the area of land on which work was carried out to protect it from water erosion, and flooding by flood control measures, deepening and clearing the river bottom, clearing reclamation canals, overhauling hydraulic structures, reclamation facilities, etc. in hectares for any period and/or in the percentage of the total area of farmland;

(3) the area of agricultural land, on which work was carried out to protect it against wind erosion and desertification through agroforestry and phyto meliorative measures (ha) for any period and/or in the percentage of the total area of agricultural land.

Target 2.5, indicator 2.5.1. As part of the subgroup of agroecological indicators, reflecting the problems of conservation and protection of bio (genetic) diversity, the following clarifying and specifying indicators are proposed:

– the number of crop varieties officially registered and certified for sale, by main types/groups of crops growing;
– varieties of crops growing, by their main species/groups, which are endangered and close to extinction, as well as within the framework of programs for the conservation/restoration of these agricultural varieties;
– varieties of crops, the genetic information of which is stored/reproduced in the required amount in specialized collections-repositories;
– the number of livestock breeds officially registered and certified for sale, by main types/groups of livestock;
– breeds of livestock by its main species/groups that are in the status of endangered and close to extinction, as well as within the framework of programs for the conservation/restoration of the livestock of these agricultural breeds;
– breeds of livestock whose genetic information is stored in the required amount in specialized collections/storages.

Goal 6. Availability and more efficient use of water resources and sanitation for the entire population.

Target 6.4, indicator 6.4.1. As part of the subgroup of agroecological indicators reflecting water resources, water use, protection and rational use of water, the following indicators can also be used concerning agricultural activities:

(1) the consumption (withdrawal) of water from natural sources, including the extraction of groundwater and with the release of fresh water, for the agricultural need—total, cubic meters. m/1,000 units GVA in the industry, in national currency, at current and/or comparable prices, for any reporting year or period in dynamics;
(2) the use of freshwater taken from natural sources, including the extraction of groundwater, for the needs of agriculture—total, million cubic meters and per unit of GVA, cubic meters/1,000 units VDS.

In addition, the indicator “change in the efficiency of water use” over time (ie the indicator of water output) characterizes the change in the ratio of value-added to the volume of water use in dynamics. Water use efficiency (EWE) is defined as the amount of water withdrawn from natural sources divided by the value-added of the relevant sector, i.e. as the water capacity of VDS. Within the framework of the updated classifier of types of economic activities, it is recommended, first of all, to make calculations for the agricultural sector, forestry; mining; hunting, fishing/fish farming; construction, collection, purification and distribution of water;

processing industries (highlighting the main subtypes of this activity); waste treatment and disposal; transport and storage; provision of electricity, gas and steam; air conditioning; collection and treatment of wastewater; collection, processing and disposal of waste; the processing of secondary raw materials, etc.

Target 6.4, indicator 6.4.2. As part of the subgroup of agroecological indicators reflecting water resources, water use, protection and rational use of water, indicators reflecting the intake/use of freshwater as a percentage of:

(a) renewable resources of this water (average annual river runoff and/or a similar runoff for the reporting period);
(b) the available reserves of fresh water in various water bodies (with the elimination of double counting when water flows from one group (type of water resources) to other groups (another type).

At the same time, water intake/water consumption indicators should relate to agricultural activities or rural areas.

Goal 7. Access to affordable, reliable, sustainable and modern energy sources for all.

Target 7.2, indicator 7.2.1. As part of the subgroup of agroecological indicators reflecting energy consumption in agriculture, the following indicators, in particular, can serve as additional indicators to expand the analysis of the progress of this SDG task concerning agricultural production/rural areas:

(1) the ratio of the volume of production (extraction) of primary energy from renewable energy sources to the volume of gross consumption of fuel and energy resources (TER) in the industry under consideration/in the relevant territory;
(2) the share of electric energy produced using renewable energy sources in the total volume of electric energy production in the industry/on the territory;
(3) the capacity of generating facilities operating based on the use of renewable energy sources (excluding hydroelectric power plants with an installed capacity of over 25 MW) concerning the agricultural sector/rural areas;
(4) the share of renewable energy sources in the total volume of final energy consumption by types of energy production (firewood, peat, biogas, hydropower, solar energy, wind energy, thermal water energy, tidal energy, other types of energy) concerning the agricultural sector/rural area.

Goal 11. Ensuring openness, security, resilience and environmental sustainability of cities and settlements.

Target 11.6, indicator 11.6.1. As part of the subgroup of agroecological indicators reflecting the problems of orderly management of production and consumption waste, additional indicators are also used that expand the possibilities of statistical analysis concerning rural areas/agricultural production, in particular:

(1) the share of the population covered by municipal services for the disposal (removal) of solid waste regularly in the total population (with the allocation of data for rural areas), %;

(2) the share of recycled (usefully used) municipal solid waste in the total volume of municipal solid waste removed (with the allocation of data for rural areas), %.

Goal 12. Transition to the most efficient models of consumption and production.

Target 12.5, indicator 12.5.1. As part of a subgroup of agroecological indicators reflecting the problems of orderly management of production and consumption waste, it is advisable to apply additional indicators relative to agricultural production/rural areas, including:

(1) the share of processed (sorted) waste in the total volume of production and consumption waste generation in the industry/in rural areas, %;
(2) the share of neutralized waste in the total volume of waste generation and consumption in the industry/in rural areas, %;
(3) the share of usefully used waste in the total volume of waste generation and consumption in the industry/in the relevant territories, %.

In this case, both wastes generated previously and during the reporting period are subject to reflection.

Target 12.8, indicator 12.8.1. As part of the subgroup of general agroecological indicators (a subgroup of indicators of specialized education and education), it is advisable to use additional indicators, such as:

1. the number of students in primary, secondary and higher education who are taught the relevant subjects within the general course of agroecology and/or similar courses, per thousand people;
2. the number of various educational activities (by their types and directions) conducted among the rural population during the reporting period (over several years) and the number of citizens who took part in them (covered by these actions)—units and thousands of people.

Goal 13. Taking urgent measures to combat climate change and its consequences.
Goal 13. Take urgent action to combat climate change and its impacts.

Target 13.1, indicator 13.1.1. As part of a subgroup of agroecological indicators reflecting the protection of atmospheric air, climate change and its consequences, including emergencies, natural and other disasters, etc.

It is advisable to use additional indicators concerning rural areas, in particular:

(1) the number of deaths as a result of emergencies, units;
(2) the number of injured, sick as a result of emergencies, units;
(3) the number of temporarily resettled, evacuated in rural areas as a result of emergencies, units;
(4) the number of dead, missing and injured in rural areas directly as a result of disasters per 100 thousand people.

Goal 15. Protect and restore terrestrial ecosystems and promote their efficient use, sustainable forest management, combating desertification, halting and reversal of land degradation and halting of biodiversity loss.

Target 15.1. indicator 15.1.1. As part of the subgroup of agroecological indicators characterizing land resources, biodiversity, Specially Protected Natural Areas (SPNA), and the activities carried out in dynamics may include the area of forests as a percentage of the total land area (forest cover of the territory).

With regard to agriculture/rural areas, it is necessary to define in the accounting and statistical plan for forest belts and other forest areas that are and are not included in the state forest fund, including water protection forests, forest areas of protected areas, etc., associated with agricultural activities/rural areas.

Target 15.1, indicator 15.1.2. As part of the subgroup of agroecological indicators reflecting the problems of biodiversity conservation, PAs (protected areas) are additionally offered indicators:

(1) the number and area of specially protected natural areas in the country as a whole, and for certain types of protected areas, allocated following national legislation and groupings of the International Union for Conservation of Nature (IUCN), units and thousands of hectares;
(2) the share of the number and area of "agroecological" PAs from the total number and area of all PAs in the country,%.

In this case, it is necessary to select PAs bordering on agricultural land plots which have a mutual influence on each other.

Target 15.3, indicator 15.3.1. Within the subgroup of agroecological indicators reflecting land and soil resources, land degradation is defined as a decrease or loss in biological or economic productivity and an increase in the complexity of cropland, irrigated arable land or range of pastures, forests and woodlands as a result of a combination of different methods, including land-use methods and management. This definition has been adopted and is used by many countries that are parties to the UN Convention to Combat Desertification (UNCCD).

The unit of measure for this indicator is the spatial extent (hectares or km2), expressed as the proportion (in %) of land that is degraded over the entire land area.

SDG indicator 15.3.1 is a binary degraded/non-degraded quantification based on an analysis of the available data on three sub-indicators that need to be validated and reported by national authorities. Sub-indicators (trends in land cover, land productivity and carbon stocks) were adopted by the UNCCD governing body in 2013 as part of the indicator's monitoring and evaluation approach. By their decision 22/COP.11, the parties to the Conference established an approach to monitoring and evaluation that includes: (a) Indicators; (b) a conceptual framework to enable the integration of indicators; and (c) sourcing and governance mechanisms at the national/local level.

Target 15.8, indicator 15.8.1. As part of the subgroup of agroecological indicators reflecting the problems of preserving and protecting biodiversity, additional indicators that make it possible to more clearly reflect the solution to this SDG target concerning agricultural production/rural areas may include the following indicators:

(a) the number of invasive species:

- growing (flora);
- living (fauna)

– in agricultural areas (agricultural land), units;

(b) the number (units) and area (hectares, thousand hectares) of quarantine sites for invasive species in general and their species (for example, plants, insects, etc.);
(c) the number of registered cases (units) of the presence of quarantine species of agricultural and related products imported in the territory of the country at the customs border during inspections, as well as the share of such products in the total volume of imports of the corresponding goods/products (%).

Target 15.9, indicator 15.9.1. As part of the subgroup of agroecological indicators reflecting the problems of biodiversity conservation, in particular, the number of national, sectoral and regional strategies and programs that take into account the value and level of conservation of biodiversity and ecosystems can serve as an appropriate specific indicator. At the same time, it is necessary to identify parts that are directly related or directly related to agricultural production/rural areas.

4 Conclusions and Recommendations

The main findings of the study are as follows:

1. The selection of SDG indicators in the field of agroecological activity has been carried out.
2. The analysis of various approaches of international organizations to the definition of the scope and structure of agroecology has been done. The evaluation of the target documents was carried out and recommendations of these organizations, as well as international standards similar in tasks and profile of agroecology, were studied.
3. These materials have been adapted to the realities of statistical theory and practice in Russia and other CIS member countries.
4. A methodology for the formation of statistical indicators for the implementation of relevant natural resource and environmental statistical accounting characterizing the interaction of agriculture and the environment in the context of global trends has been developed.

In the course of this study, 16 SDG indicators that have a certain relation to agroecological statistics were identified and examined in detail within the framework of 7 relevant goals and 13 tasks. The principles and approaches to the formation of a system of agroecological indicators used in the main international standards and recommendations were taken into account.

As a result of a comprehensive analysis of the main goals of the SDGs, the proposed system of indicators allows for a statistical assessment of the role of agriculture in rural areas in preserving biodiversity, greenhouse gas emissions from agricultural production and rural areas, the production of raw materials for biofuels, and the provision of environmental services.

The analysis of the SDG indicators is carried out for obtaining reliable statistical information and the methodology of their calculation, as well as for further implementation in the practice of statistical accounting. In addition, editorial refinements of the formulations of these indicators were carried out to adapt them to the existing accounting and statistical observation systems in the CIS countries.

It is recommended to use the proposed system of indicators for agroecological accounting within the framework of the Sustainable Development Goals in the practice of statistical work in Russia and other CIS countries.

However, there will be certain difficulties in the process of obtaining some indicators when introducing SDG indicators into the practice of statistical accounting in Russia and other CIS countries. This is primarily related to the fact that the current principles of classification of land resources (for example, by categories of land) differ significantly from the international recommendations described above.

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Green Energy Stimulating State Policy as a Factor of New Economic Cycle Formation

Igor A. Basko

Abstract The growing attention of the world community to climate and ecology problems caused a spiral of development of scientific, political, and economic thought in this direction. Within the framework of the Industry 4.0 paradigm, it becomes relevant to study the transition of the economy to a new next level of development with the qualitative use of new technologies and alternative energy sources. This article provides a comparative analysis of the economic policy of some states, which is aimed at the systemic reduction of harmful emissions in the atmosphere, as well as a measure to stimulate corporations to switch to new energy sources. Research provides evidence of effectiveness and usefulness measures in the field of state support for a large-scale transition to green energy as a factor formation and development of the current stage of transformation of the world economy. Besides, the article concludes that a new phase of the long-term economic cycle has begun, which contributes to the diversification of production, reduction of dependence on traditional energy sources and the implementation of the paradigm of long-term development.

Keywords Green energy · Economic cycle · State policy

JEL Codes G15 · O44 · O31 · Q4

1 Introduction

One of the driving factors of the transition to new economic development is a qualitative shift from the use of fossil energy sources to such energy as wind and water. For several decades, fossil fuels will continue to underpin many of the core activities that enable modern society to function. In most cases, the complexities of different energy sources are not considered, including the variability of production, the need to replace massive infrastructure networks and the lack of interchangeability of various energy sources. Integration approaches can help balance interdependent factors such as clean energy dynamics, resource allocation, and ecosystem degradation. Ways

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_4

of investing in energy and climate lead to trade-offs between economic output and quality of life, which are necessary. Accordingly, the development of future energy policy requires an approach with global boundaries and a new level of understanding of the totality of interrelated factors.

There a lot of modern research identified the convergence of commodity cycles, including the dependence of the movement of several key commodity groups on energy assets (Vacha & Barunik, 2012). The growing innovation trend of the introduction of new technologies into the economy has led to a high rate of research, implementation and development of new production methods and more active use of alternative sources of energy, which also influenced the transition of the world economy to a new phase of the emerging long-term cycle (Akaev, 2009).

The global transition to clean energy is underway (Russo, 2021) and it is becoming one of the top priorities for the largest states. This goal came to the fore because global carbon emissions continue to grow, albeit at a slower pace. Therefore, the world's population is growing by 80 million every year. This will increase energy consumption in absolute terms.

Over the decades, there has been an increase in the number of substituted hydrocarbons, which together provide about 84% of the world's energy (IEA, 2021). Clean technology is the tool to meet this challenge—a great example of the potential multiple exponential growths that will remove fossil fuels from the market over the next 10 years (Seba, 2017). Green technologies such as batteries, solar energy and wind energy are improving much faster than most people think. It's comparable to the largest transition to a new cycle of economic rescue since the industrial revolution. For example, by 2030 the cost of solar energy may be practically free, which will make it possible to use it as efficiently as possible everywhere (Solar Energy Technologies Office, 2021).

The objective of the research is a systematic analysis of the dependence of the economy in the transition from the current state with the dominance of traditional energy resources use to green energy and the role of states in the formation and development of this process.

2 Material and Method

This research was based on the Prudence and Predictive methodology in cooperation with analysis of fluctuation dependences of the economy and consisted of three stages. The novelty of the study is also confirmed by the need for a qualitative review of trends and structural shifts in the transition of the world and Russia to renewable energy sources, which is due to the formation of a new economic cycle, synchronously emerging in developed and developing countries.

At the first stage, key global energy trends, benefits and costs of the transition to green energy were identified, the strategy for the movement of the world power and the Russian state in the field of support and development of measures to reduce emissions and increase investment in clean energy was analyzed.

The following sources of information were used: Publications indexed in Scopus; Web of Science databases; Publications in business and industrial magazines; Strategic and analytical documents of international organizations, companies, government bodies, research and analytical centres, financial institutions such as the International Monetary Fund (2017), IMF Annual Report (2021), OECD (2020), Statistical data and forecasts of the International Energy Agency (IEA, 2021), the International Renewable Energy Agency (IRENA) (2020), the Solar Energy Technologies Office (2021), the European Commission (2021a, 2021b), the Global Wind Energy Council and other organizations Accenture (2021), Electric Transport Revolution Set to Spread Rapidly into Light and Medium Commercial Vehicle Market (2021), Wells Fargo Investment Institute (2020).

At the second stage of the research, the main features and practical actions of states in a comparative and predictive systemic nature are identified, which are fundamental in the modernization of energy and directed offensive periods of economic development.

The third stage is based on the elaboration of proposals for Russian companies and public authorities. The recommendations were prepared by expert methods based on data on Russia's green energy development programs, reduction and expansion of the investment paradigm, publications of analytical studies; analysis and resolutions.

2.1 Commodity Cycles

The beginning of the industrial revolution served as the basis for the growth of the population and the volume of consumption of natural resources. The growing demand for raw materials and goods pushes up the prices of energy, metals, agriculture, etc., while prices often change synchronously (Economist, 2021).

Many economists believe that the recovery phase in the supercycle is the period between steady trends in demand for commodities with a slowly changing supply. Commodity groups of different types have their price patterns of behaviour, but when plotted on a chart together they form long periods of price trends called "commodity supercycles" (Economist, 2021) when there is a recognizable model for the main commodity groups. The supercycle coincides with long periods of industrialization and modernization (Fig. 1).

Since 1899, there have been four different commodity price supercycles. From the rapid industrialization of America becoming a world power at the beginning of the twentieth century to the rise of China at the beginning of the twenty-first century, historical periods of growth and industrialization are stimulating new demand for goods (Fig. 2). The rapid industrialization and growth of a nation or region are the main drivers of these commodity supercycles.

In our opinion, the following key stages of industrialization can be distinguished:

– USA industrialization (1900–1933);
– Global rearmament of the II World War (1933–1962);

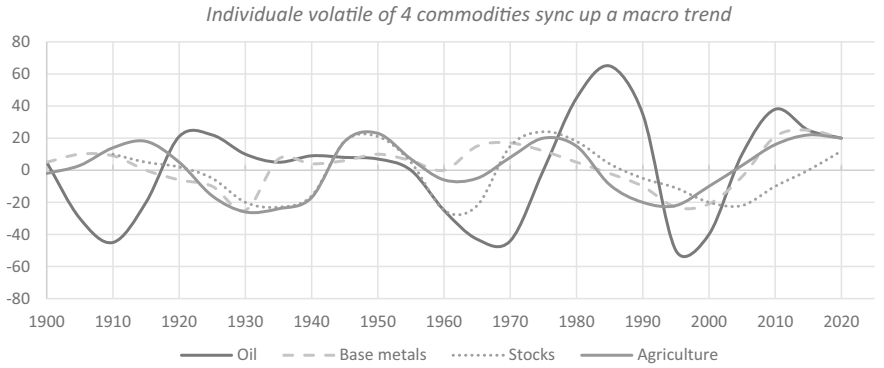

Fig. 1 Price Cycle across commodities. *Source* Calculated by the author based on Bank of Canada. https://www.bankofcanada.ca/rates/price-indexes/bcpi/

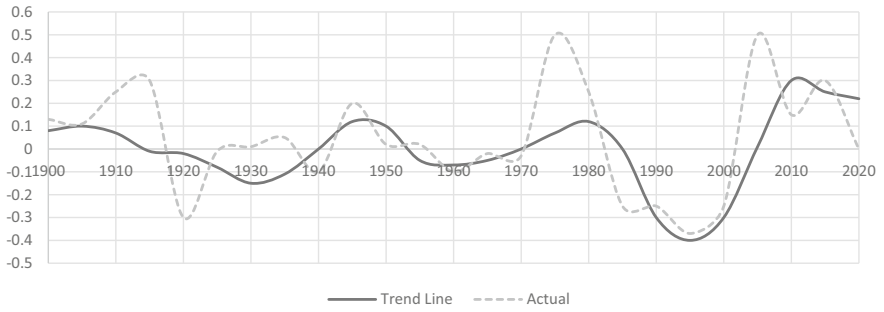

Fig. 2 Supersycles in commodity prices. *Source* Calculated by the author based on Bank of Canada. https://www.bankofcanada.ca/rates/price-indexes/bcpi/

– Reindustrialization of Europe and Japan (1962–1996);
– The rapid industrialization of China (1996–present).

Since the supply of goods on the market often occurs with a delay, prices decrease after the restoration of supply and a decrease in demand. Previous growth rates around the world were asymmetric: different countries accounted for the predominant share of commodities at certain intervals. This was reflected in the dynamics of commodity prices within long cycles, which were replaced by periods of active growth, slowdown and recession (Tables 1 and 2).

3 Results

In the era of dynamic globalization, the demand for goods has become more symmetrical: goods will be constantly in short supply, changing the usual dynamics of cycles.

Table 1 Growth period

Commodity bull super-cycles		
	Percentage gain	Length (years)
1896–1920	268.70%	24
1933–1951	331.50%	18.3
1971–1980	249.50%	9.1
1999–2008	291.80%	12
Average bull	285.4	19.8

Source Compiled by the author based on Bloomberg. https://www.bloomberg.com/professional/blog/metal-bulls-its-not-a-super-cycle-yet/, Wells Fargo Investment Insitute (2020), Bureau of Economic Research. https://www08.wellsfargomedia.com/assets/pdf/personal/investing/investment-institute/ID_072321_ADA.pdf

Table 2 Recession period

Commodity bear super-cycles		
	Percentage gain (%)	Length (years)
1920–1933	−65.70	12.8
1951–1971	−38.60	20.4
1980–1999	−45.70	15.6
2008–2020	−73.20	11.7
Average bear	−55.80	15.1

Source Compiled by the author based on Bloomberg. https://www.bloomberg.com/professional/blog/metal-bulls-its-not-a-super-cycle-yet/, Wells Fargo Investment Insitute (2020), Bureau of Economic Research. https://www08.wellsfargomedia.com/assets/pdf/personal/investing/investment-institute/ID_072321_ADA.pdf

This is especially reflected in the energy market, which is the base for all sectors of the economy. Resource scarcity leads to efficient energy sources. It is worth noting the presence of a direct correlation between the dynamics of the global economy, energy consumption and carbon dioxide emissions into the atmosphere: thus, in 2021, the global economy decreased by 3.3%, while energy consumption decreased by 3.5% compared to 2020 and CO_2 emissions showed a trend of minus 5.2% compared to the previous year.

In this regard, the influence of states on the formation of institutional principles, rules and methods of interaction between economic entities in the field of regulatory and economic measures for the formation of pricing policy in the energy consumption market, control and reduction of emissions into the atmosphere, stimulation of the transition to environmentally friendly and renewable energy sources come to the fore.

3.1 State Policy to the Green Energy Transition

The world is undergoing a global energy transformation based on technological changes and the building of updated political and economic priorities (OECD, 2020). The onset of the 4th phase of the energy transition leads to a large-scale using renewable energy sources and replacing the share of fossil fuels. Over the past 20 years, we have seen several political and economic initiatives to reduce environmental emissions. The focus of the authorities is mainly on the effectiveness of climate policy, while in parallel, an irreversible technological energy transition continues, which is gaining an active impetus in a spiral.

We denote the key drivers of the transition to green technologies:

1. Climate Agenda and Decarbonization Goals.
2. The desire of the governments of all countries to ensure the competitiveness of national economies and accelerate their economic growth through universal access to affordable electricity.
3. Striving to improve energy security by reducing dependence on imports of hydrocarbons and increasing supplies from local efficient low-carbon sources.
4. Technological progress and the emergence of completely new technological solutions can significantly increase the solutions that can significantly increase the efficiency of resource use in the energy sector and improve the usual principle of its functioning.

For decision-makers, the priority of the actual macroeconomic measures, which determine economic development, the rate of economic growth, and the well-being of the population, is obvious. This includes making adjustments to tax policy, reforming the subsidy policy, which in most cases leads to degradation of the use of natural resources and detrimental effects on the environment. These activities are aimed at increasing the competitiveness of environmentally friendly resources and services. In 2019, over 600 investment firms with assets under management of over $37 trillion called for the end of government fuel subsidies (Egorova, 2014).

Thus, challenges for states and economies in the transition to a new energy model in our opinion include:

1. Transformation of the institutional framework: changing the existing models of electricity markets and pricing support.
2. Stimulating scientific and technical research.
3. Increased inter-fuel competition in all sectors, new players support.
4. Revising & supporting changing of corporate strategies.
5. Risks of losing existing investments negotiation.
6. A downward spiral of demand for fossil fuels, loss of global influence.

The IEA predicts that the share of all renewable energy sources (including hydropower and bioenergy) in global production will grow from 26% currently to 44% by 2040. Meanwhile, the share of fossil fuels in global primary energy demand will only decline from 81% now to 74% in 20 years (IEA, 2021). This proves the steady development of a new trend in the growth phase of a new economic cycle.

Many countries have introduced subsidy schemes to increase the share of alternative environmentally friendly energy sources (mainly in the electric power industry) and thus reduced the share of electricity generated by conventional power plants. Thus, investing in green energy sources were the driving force behind the transition to low-carbon technologies. Globally, from 2010 to 2017, this averaged nearly $300 billion per year (Hanley, 2018). Cumulative investment in renewable energy could reach $8 trillion by 2040. Renewables will account for 35% of total energy consumption; the greatest growth is expected in the wind and solar energy.

Achieving climate targets with the technologies policymakers will have to remove fossil fuel subsidies, especially to levy high carbon taxes or price their emissions through an emissions trading system. The tax on polluting carbon emissions must be increased regularly until certain emission reduction targets are achieved, which in turn will stimulate technological innovation, its adoption and large-scale infrastructure development. It is similar to the growth of the smart technology adoption cycle and the emergence of new devices in the early 2000s. We can now see the widespread adoption of clean energy technologies at the same pace as the widespread adoption of clean energy today. The transition to green energy in the next 30 years will cost 15 trillion dollars to taxpayers. About 80% will go to renewable energy sources. In addition to investments in the production of wind and solar energy, significant environmental costs are required (Oil Price, 2020).

In Latin America, where governments like to support citizens with subsidies, received record foreign direct investment inflows in 2019, overtaking the Asia–Pacific region and coming second behind Europe. The largest share of foreign direct investment (40%) was in Brazil, which is also a major oil producer (OECD, 2020).

Currently, in Europe, no more than 9% of companies have sufficient capacity to regularly and accurately calculate their emissions into the atmosphere. Only 5% of Europe's largest listed companies meet their zero-emissions commitments. 30% of these companies have committed to achieving zero by 2050, while 9% of them will be able to achieve the target if they continue to decline between 2010 and 2019. Renewable energy weight in electricity Europe's 2020 output surpassed fossil fuels for the first time in history. In 2020 20% of the electricity in the EU countries was generated by solar and wind power plants. This is also one of the reasons why coal-based energy production dropped by 20% last year - coal plants provided only 13% of the electricity generated in Europe. The highest shares of wind and solar energy generation are reported to be recorded in Denmark (61%), Ireland (35%), Germany (33%), and Spain (29%).

The U.S. Securities and Exchange Commission (SEC) has decided to take an alternative position on climate risk disclosure than its European counterparts. The SEC has focused its efforts on supporting companies and their executives who implement measures to invest in reducing emissions, unlike European regulators, who often focus on investment funds.

It turns out that from 2020 to 2050, $14 trillion will need to be invested in the construction of infrastructure energy networks and their adaptation to renewable energy sources. Their share is expected to rise to 56% by 2050. By comparison, the oil industry accounted for 24% of the S&P 500 in 1982. Today it is less than 3% we

are seeing an 80% loss in relative value over 40 years. Over the past decade, 1,200 climate startups have been created around the world for a total of $60 billion (Global Renewables Outlook, 2020). This trend indicates an increase in investor interest in active energy transfer based on alternative energy, as a factor in the accelerated turn of the economic cycle.

In the past seven years, the venture capital money toward replacement industries has gone from $420 million, a puny amount, to $16 billion. U.S. businesses cut their carbon intensity by nearly half over the past decade. The economy is organically reducing its dependence on carbon emissions.

3.2 Russia

The current crisis has become a serious challenge for the entire Russian economy and the financial sector in particular. Additional measures of fiscal and monetary policy are still insufficiently synchronized. Structural changes are related not only to the crisis but also to changes in supply and demand. There are many new trends such as segmentation of the financial market, digitalization, regionalization, the search for sources of financing by most companies, which require a serious revision of the strategy for further development. Globalization unfolding in the world in recent decades increasingly reduces the ability of national governments to choose one or another option for changing taxes and government spending. For the Russian context, the global low carbon trend is fundamentally important due to the declared priorities for reducing the consumption of traditional hydrocarbons by the main consumers of the country's energy resources (Bobylev et al., 2019).

Bloomberg reports the fourth largest greenhouse-gas polluter, Russia dumps about 5% of all carbon dioxide into the atmosphere each year. Nearly 90% of all energy Russia consumes comes from carbon-heavy sources, above the global average of about 80%. The share of hydroelectric power plants of nuclear power plants of solar and wind power plants in Russia exceeds 37% (Mitrova & Melnikov, 2019). Accelerated deployment of renewables could save the country as much as $11 billion a year by 2030. Russia is planning to absorb 1.1 billion tons of CO2 in 2019 up to 2.58 billion tons in 2050. The cost of implementation is 1.5% of GDP (Proskuryakova & Ermolenko, 2019).

The Russian government has developed a program of measures to curb climate change, environmental development of the country until the 2030 year. About 34 billion rubles will be allocated for the implementation of the strategy until 2030. The state has a climate strategy in three directions:

- Monitoring and forecasting the state of the environment.
- Litigation of human impact on nature.
- Adaptation of natural systems and all sectors of the economy to climate change.

It is important to form mechanisms for financing green development, which make it possible to assess the needs of society in the development of environmental infrastructure, taking into account losses from natural disasters and environmental damage from anthropogenic activities. One of the conditions for overcoming the existing structural imbalances seems to be an accelerated reduction in unit costs in the energy sector. Investments should be formed through the development of mechanisms for the redistribution of excess financial resources generated in the export, raw materials and financial spheres. In our opinion, the main directions of development of the Russian economy within the paradigm of "Industry 4.0" should be the following:

- technological modernization of the economy;
- the entry Recognition of Russian technologies in the world market;
- introduce a system of tax incentives for organizations;
- close interaction with regions and use of opportunities, including in international trade.

Important tasks for the promotion and implementation of the concept of green growth in Russia are active actions to apply a set of national green economy indicators aligned with OECD principles:

1. Principles of integrating innovations
2. Monitoring and control of growth rates and indices of carbon footprint accounting;
3. Expanding the application of the results obtained in partner countries.

The transformation of the energy sector will lead in the future to a decrease in the contribution of the oil and gas industry to the structure of the Russian economy. The chosen course of the state for the development of alternative energy sources will give a new impetus for GDP growth. Electric cars squeeze the oil market but give new impetus to the demand for electricity. This opens up additional opportunities for the sources of its production. Now the global oil demand is about 100 million barrels. By 2030, about 28% of cars sold will be electric, and by 2040—57%. By 2040 electric vehicles will reduce the demand for motor fuel by 13.7 million barrels per day (Electric Transport Revolution Set to Spread Rapidly into Light and Medium Commercial Vehicle Market, 2021). These require a decisive economic and energy policy to adapt the country to the Energy Transition. These data confirm that the development of the world economy leads to an active increase in energy consumption and reflects the formation and development of a growing phase of a new raw material economic cycle, while the Russian Federation is also actively developing towards the transition to environmentally friendly energy sources and reducing the influence of traditional minerals in the structure of the state budget.

4 Conclusion

Climate protection measures need to be significantly more effective as financial resources to combat climate change are limited. Since it is unlikely that such a price will be introduced globally, emissions trading involving as many G20 countries as possible would be a huge step forward:

- developing cross-industry collaboration to ensure the availability and scalability of low carbon solutions;
- the availability of electric vehicles will help electrify and decarbonize the vehicle fleet in the transport sector;
- increased impact on industry and value chain mobilization. Large companies can achieve much greater reductions in greenhouse gas emissions;
- fostering innovation: Investing in clean energy technologies can be the most effective way to reduce environmental emissions;
- digitalization.

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Study of "Digital Portraits" and Value Priorities of Rural and Urban Residents as a Component of Strategic Planning and Forecasting of Rural Socio-economic Development

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Abstract The paper analyzes the value priorities of urban and rural residents to identify factors influencing the positive and negative perception of rural lifestyles to form proposals that contribute to a positive image of the village and the conditions for sustainable development of rural areas. The novelty of the research lies in the fact that the authors applied big data analysis to determine the socio-demographic characteristics of users of social networks, expressing the intention to move to rural areas. For this purpose, the authors formed a register of users of the social network "VKontakte," including 1,828,232 profiles. Based on digital traces, the main values (motives) of users willing to move to rural areas are highlighted, and the problems associated with living in rural areas are identified. The psychological testing involved 2104 respondents living in the Republic of Bashkortostan, Stavropol Territory, Krasnodar Territory, Kirov Region, Tambov Region, Saratov Region, Sverdlovsk Region, Samara Region, Belgorod Region, and Pskov Region. The obtained results allow us to outline the main directions of work to influence the behavioral patterns of urban and rural residents to change them in the direction of forming a positive image of rural areas and moving to them for permanent residence and work in agriculture.

Keywords Values · Image of the village · Readiness of different categories of the population to move and work in rural areas · Big data

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_5

JEL Code C89

1 Introduction

The key criteria for the sustainable economic development of rural areas are stable growth and increased economic productivity of the rural economy based on balanced reproduction of productive potential and its rational use. In this case, the role of the social component is to constantly improve the quality of life of the rural population, stabilize migration and demographic processes in rural areas, maintain traditions and culture, and involve the population in decision-making to ensure the stable development of rural areas. The sustainable long-term development of rural areas can be achieved only if the development of social, institutional, and environmental components is balanced (Fidorenko, 2015).

One of the main objectives of the Federal program of the Russian Federation "Integrated development of rural areas" is to maintain the share of the rural population in the total population of Russia at the level of at least 25.1% in 2025. In this regard, issues related to attracting population for permanent residence and work in rural areas (return migration) and the preservation of the potential of the rural population are critical and urgent.

Proponents of reverse migration emphasize its positive impact on the socio-economic organization of rural areas, especially in times of demographic and economic decline. Many scholars have noted that migrants become new economic actors who bring diverse capital and a flood of new ideas for reconstructing sedentary agriculture (Bosworth, 2010; Stockdale et al., 2013). However, some authors find the negative side of reverse migration. Urban citizens make life difficult for local people: they build luxury housing in the countryside, turning locals into servants. As a result, the term "colonization" of the countryside by city dwellers was created (Taylor, 2011). Reverse migration creates contradictions and conflicts between migrants and locals (Löffler & Steinicke, 2006; Murdoch & Lowe, 2003).

Studying the issue of return migration in Russia, V. I. Zvyagintsev and M. A. Neuvazhayeva revealed a logic that is the opposite of reverse migration in Western countries in many ways. The analysis of interviews with immigrants showed that it is primarily the middle-class representatives who move from the city to the countryside; many of these people have already had the experience of living in the countryside. The main type of employment for most migrants is labor in private subsidiary farms or organizing farms. Alternative types of employment in the service sector, of which there is much talk in Western studies, are almost absent. In most cases, the migration was motivated by the economic conditions prevailing in the city. The inability to maintain urban consumer standards due to limited resources and cope with the risks of urban life are the main reasons contributing to reverse migration in Russia. Nevertheless, having moved to the rural area, people do not become active subjects of the renewal of rural life (Zvyagintsev & Neuvazhaeva, 2015).

Studying the motives of migration (from rural to urban and from urban to rural areas) and the role of this factor in the development of rural areas, we come to such a concept as the "lifeworld" of a person. This concept includes such deep qualitative characteristics as "meaning of life," "values," and "needs," reflecting the main and essential contained in the social consciousness and behavior (activity) in a certain social environment.

2 Materials and Methods

The research aims to analyze behavioral patterns of residents of urban and rural areas to identify factors influencing the negative and positive perception of rural life to form proposals contributing to a positive image of the village and the conditions for sustainable development of rural areas.

Research objectives are as follows:

1. To determine the readiness of various groups and categories of the population to move to rural areas;
2. To identify the spectrum of values influencing the positive image of the perception of rural areas;
3. To determine the positive perception of the possibility of moving to rural areas by different groups and categories of citizens;
4. To identify attitudes of residents towards state initiatives and projects for the development of rural areas;
5. To identify infrastructure characteristics relevant to the decision to migrate.

A total of 2104 respondents participated in psychological testing. The average age of the participants was 31.45. The composition of the sample is as follows:

- Schoolchildren (6.1%);
- Students (18.4%);
- Working professionals (50.5%);
- Unemployed specialists (21.3%);
- Pensioners (3.7%).

The sample is well-balanced by gender: men make up 48.3% of the total number of respondents, and women—51.7%. The testing involved respondents living in the Republic of Bashkortostan, Stavropol Territory, Krasnodar Territory, Kirov Region, Tambov Region, Saratov Region, Sverdlovsk Region, Samara Region, Belgorod Region, and Pskov Region. Regions were classified by the socio-economic situation, migration indicator, and quality of life into three groups: positive, neutral, and depressed.

Big data analysis was applied to achieve the goal and objectives of the research. For this purpose, we formed a register of users of the social network "VKontakte" interested in rural life and relocation. The registry included 1,828,232 profiles. We

assume that the obtained data on the number of digital population can be extrapolated to the entire population of the region, using the rationing procedure.

A specially designed questionnaire "Attitudes towards rural areas" was used as a psychological testing technique.

The questionnaire consists of five blocks:

- The image of the village (images, representations, stereotypes, positive–negative context, etc.);
- Integration (readiness to move to rural areas, to be included in the specifics of rural life, what is needed for this, etc.);
- Activity (what respondents are ready to do in the village, what activities to engage in, and what projects to support);
- Informational (awareness of support programs, ways and possibilities of resettlement, satisfaction with the information received, and missing information);
- Auxiliary—identifying additional factors that may influence respondents' attitudes toward moving to rural areas.

We calculated an index of readiness to live in rural areas for each respondent. This index was used to analyze the results and responses to particular questionnaire items.

Statistical processing of the results was carried out based on the computer package of statistical programs SPSS v 21.0 in the following sequence:

1. Methods of descriptive statistics were used to calculate indicators of average values—for each of the studied groups of respondents, allocated based on the research objectives. The indicators of the following groups were considered separately:
   (a) All respondents of the survey;
   (b) Respondents with different levels of readiness to live in rural areas;
   (c) Respondents living in different regions;
   (d) Respondents of different ages living in rural areas;
   (e) Respondents of different ages with a high level of the index of readiness to live in a rural area;
   (f) Female and male respondents;
   (g) Respondents living in cities, oriented and not oriented to move to the countryside;
   (h) Respondents living in rural areas, oriented and not oriented to move to the city.
2. Comparison of subgroups according to the choice of answers in the questionnaire "Attitudes towards rural areas" and identifying the significance of differences between the data obtained was carried out using the chi-square (Pearson's agreement criterion).
3. A nonparametric Mann-Whitney test was used to confirm the hypothesis of differences (when comparing individual indicators of two groups).

4. A nonparametric Kruskal-Wallis test was used to confirm the hypothesis of differences (when comparing individual measures of the three groups).

The analysis of respondents' answers to open-ended questions related to the identification of the value of life and work in rural areas was conducted using PolyAnalyst software. Big data analysis was carried out using software tools that allow working with big data.

3 Results

The analysis of the obtained data allowed us to create psychological portraits of the categories of the population with different degrees of readiness to move to rural areas. The respondents with a high level of readiness to live in rural areas can be characterized as follows. They feel good about rural life, with the likelihood of moving to the countryside greatly increased if they can get some social benefits. They are ready to integrate into life in rural areas, while only some of them plan to engage in agriculture. They are more informed about many rural development projects and more often recognize their relevance. Their attitude to life in rural areas is largely reasonable; they rely on their life experience or the opinion of relatives and acquaintances.

This group of respondents mainly includes people with a family and children or in a partnership relationship. Additionally, many respondents in this group live in regions with the favorable socio-economic situation. Respondents with a low level of readiness to live in the countryside are often unable to justify their attitudes toward the countryside. They have little experience living in rural areas, almost half of them do not have relatives living in the villages, and they are less familiar with rural development projects. The majority of this group is not ready to move, even if certain benefits from the state will be provided. Some of the participants in this group have anxiety about moving in general, not just about moving to the countryside—this differs somewhat from the rest of the respondent group. Some respondents are ready to move to the village if they receive benefits. They are not ready to engage in agriculture and plan to work remotely. Many of the respondents in this group can probably draw either on negative stereotypes about life in the village or on the unfavorable attitudes of their relatives towards the village. Their expectations of life in the village are irrelevant to the present circumstances. Respondents in the group with an average level of readiness to live in rural areas have a neutral attitude toward rural areas; they probably recognize both the advantages and disadvantages of rural life. Many of these respondents have inflated expectations about moving to the countryside. This group of respondents can be characterized as the most heterogeneous in their attitude to rural areas; it is difficult to predict the likelihood of their relocation. Perhaps the ambivalent attitude towards the village among some of these respondents is due to the fact that most of them live in depressed socio-economic areas. Thus, for the successful development of rural areas on the issue of return migration, it is necessary

to focus on citizens who have formed the sense of life in the village, who clearly understand what they need to live in the village and what awaits them there, who have sufficient understanding and experience of life in rural areas, who created a family, and who have sufficient psychological base in the form of their personality and the support of their neighbors.

Respondents living in positive regions expressed a greater willingness to live in the countryside. It is likely that the higher standard of living and well-being of survey participants living in positive regions allows them to view life in the countryside not as difficult circumstances but as opportunities before them. Respondents living in depressed and neutral regions were less ready for rural life. Simultaneously, respondents living in neutral regions demonstrate a lower level of readiness to move to the countryside. Respondents living in depressed regions occupy an intermediate position between the other groups; they demonstrate an average readiness to move. On the one hand, due to the weaker socio-economic situation, respondents in this group may negatively assess the move to the village, which is associated with high costs of relocation to a new place. On the other hand, some respondents probably hope that moving to rural areas will help them get benefits, improve their housing conditions, etc.

The attitudes of respondents of different ages living in rural areas towards rural areas are as follows. Schoolchildren have more negative attitudes toward life in rural areas compared to other groups of respondents. The majority would like to move to the city; they are not ready to engage in agriculture and have a low opinion of the relevance of rural development projects; they are not aware of several projects on rural development. Simultaneously, the analysis of their answers suggests that they have not formed their own informed judgment about life in the village; their dissatisfaction with rural life is superficial. Perhaps they are not so much expressing an independent view of the countryside as they share their peers' opinions, because conformism is characteristic of young people of this age. Nevertheless, schoolchildren recognize the positive aspects of life in the countryside. For example, many respondents in this group are aware of positive examples of moving from the city to the countryside. A third of the respondents in this group are willing to live in the countryside if there is an opportunity to earn more than in the city; they recognize the positive aspects of life in rural areas. Mature respondents were positive about life in the countryside. They recognize the relevance of rural development projects and are aware of them. However, this group of respondents also spoke negatively about working in agriculture, choosing to work remotely on a computer. Respondents of young age (19–35 years old) occupy an intermediate position between the first (13–18 years old) and the third (36–60 years old) groups by most indicators. On the one hand, respondents of a young age are rather positive about life in rural areas, and some of them are willing to work in agriculture. They appreciate the relevance of rural development projects (higher than the other groups) and are informed about many projects. On the other hand, half of them would prefer to move to the city from the countryside. The motivation of these respondents is likely to be more contradictory and heterogeneous than in the other two groups of respondents. According to the

specifics of the answers of this group of respondents, their own housing is a significant issue for them. Thus, the likelihood that they would stay in rural areas would be higher if they were given the opportunity to participate in a preferential rural mortgage. Additionally, the possibility of active leisure (e.g., cafes, stores, parks, etc.) is important for this age group. Therefore, the development of the service sector in rural areas is an important factor in attracting this age group to work and live in rural areas.

Most of the respondents in the age group from 19 years and older want to live in the countryside; they are more interested in the countryside near the city. The negative attitude of young respondents (13–18 years old) to the countryside is associated with the fact that it is "boring, uninteresting, and unpromising" in rural areas. However, 21.1% of them chose the answer "I would like to live in the countryside regardless of all possible disadvantages." It can be assumed that these respondents demonstrate a positive attitude to the countryside but are not ready to justify it. This gives reason to think that it is possible to increase the motivational readiness of this group to live and work in rural areas with proper vocational guidance and the formation of territorial identity among schoolchildren. Over 25% of respondents in each age group (13–18 years old, 19–35 years old, and 36–60 years old) are preparing to move to the countryside at a relatively close time, looking for possible variants, or already moving.

When deciding to move to the countryside, the most important condition is a comfortable living environment for the family. A quarter of the respondents in the second and third age groups are willing to work in agriculture, highly evaluating the relevance of such rural development projects as "Agricultural production," "Development of farming institute," "Land doctor," and "Far Eastern hectare."

Men have a slightly higher readiness to live in the countryside than women. They more often associate the move with career goals; for example, they hope for higher opportunities to develop their own business in rural areas. Probably, if we build programs designed specifically for men to attract them to rural areas, then it is necessary to place additional emphasis on these opportunities. It was found that men are more aware of rural development projects than women.

Respondents living in rural areas and not oriented toward moving to the city have the following characteristics. Most of the respondents in this group are married and have children. These respondents were more likely to live in positive regions and less likely to live in depressive regions. They express their willingness to work in agriculture and, in general, speak more positively about life in the countryside while being more willing to justify their opinion of the countryside. These respondents have more adequate expectations for rural life—they value the comfort for their families and the opportunity to develop their own businesses and social benefits. Additionally, they recognize the relevance of most rural development projects. Respondents who live in rural areas and focus on moving to the city are younger, often unmarried, and have no children (due to their younger age). They are positive not only about moving to the city but about moving as such in general. This group of respondents is marked with unreasonable expectations about rural life. They are not always ready to justify

their negative opinion about life in rural areas. Simultaneously, they are less likely to recognize the relevance of rural development projects.

Using big data analysis, the attitudes of users of the social network "VKontakte" (digital population) towards life in rural areas in the regions selected for the study were revealed.

Rural communities in the social network "Vkontakte" are represented in explicit and implicit forms. Explicit communities are communities of rural settlements in the pilot regions of the study. Implicit communities are thematic communities that broadcast values and features of rural lifestyles. We collected two registries of communities relevant to rural life:

- 200 communities on hypotheses about users who could potentially consider moving to the countryside;
- 4855 communities of rural settlements in pilot regions.

One of the research tasks was to find, describe, and quantify rural users. For its implementation, we formed a register of rural users of the social network "Vkontakte." The registry included 1,828,232 profiles and consisted of three thematic parts:

- Potentially ready to move to the countryside;
- Those with experience of living in rural areas;
- Users interested in rural life topics.

We assume that the data obtained on the number of the digital rural population can be extrapolated to the entire total population of the region, using the rationing procedure.

Thus, summarizing the obtained data, we can draw the following portrait of the "digital population" with interest in moving to the countryside:

1. Middle-aged women (36–55 years old) who are married and have already completed their education express their intentions to move to rural areas most clearly – their share prevails in communities that broadcast the values of rural lifestyle and communities for moving from the city to the countryside; they are interested in the cultural characteristics of rural life and the experience of other people in moving to rural areas. Middle-aged men (36–55 years old) are also potentially ready to move; they are more interested in buying or building real estate in the countryside, rural business opportunities (farming), and hobbies that can bring additional income (fishing and hunting).
2. Women (67%) and young people (18–35 years old) are more likely to have experience of living in rural areas, a third (33%) of users are aged 36–60 years old, and only 6% are pensioners.
3. Women are the most active users, openly expressing their opinions in social networks, leaving likes, comments, and reposting messages about rural life. The share of active men is only a quarter (24%).

To identify rural values, motives, and problem areas, a discourse analysis of 3,937,765 messages in 4855 rural communities over the past year was conducted.

Based on the analysis, we identified the main values (motives) of users for moving to the countryside and the problem areas of rural territories.

4 Discussion

The analysis of respondents' indicators demonstrates that the readiness to live in rural areas increases with age. Many respondents with high rural readiness were born in the countryside and spent their childhood there. Respondents focused on moving to the countryside place more importance on comfortable living conditions for the family and the opportunity to develop their own business. They demonstrate a high readiness to integrate into rural life. They are familiar with positive examples of moving from the city to the countryside. Additionally, they consider the development of agricultural production, the development of the institution of farming, increasing the comfort of living conditions, improving housing conditions for the rural population, and the development of rural health care to be more relevant areas for the development of rural areas. Most of them live in large cities. Most of the respondents in this group are married and have children.

On a regional basis, we can conclude that almost all regions confirm their initial status as depressed or positive. That is, the analysis of respondents' answers and social networks provides information that can be extrapolated from the virtual environment to the real world and help draw conclusions about the current state of the regions.

5 Conclusion

The analysis of the obtained data allowed us to identify the main problems underlying the formation of a positive image of rural areas and affecting the sustainability and comprehensiveness of their development. This is primarily the fact that respondents of school-age (13–18 years old) are the least positive about living and working in the countryside than other age groups. This age group is a strategic resource for long-term sustainable development of rural areas, human resources capable of implementing an innovative approach to farming. In this regard, it is necessary to develop fundamentally new approaches to today's adolescents and young people in the educational process on the formation of creative personality identifying oneself with the place of residence and focused on solving the problems of socio-economic development of the region.

The next important problem identified in our research is the lack of awareness of respondents about life and work in rural areas, which greatly affects the creation of a positive image of rural areas. On the one hand, respondents were not very active in searching for information of interest, except for communication in social networks. On the other hand, the mass media provide insufficient information to help create a

positive image of the village in a structured way and motivate people to move to the countryside.

Respondents often noted the lack of strategic planning in many territorial entities. Rural development is impossible without a well-developed strategic plan. For this purpose, in addition to studying the resource component of rural areas, it is necessary to conduct a thorough study of the requests of target groups and only then prepare ideas for implementation. It is also possible to perform identification of problem areas in rural areas through the analysis of "digital footprints" with the identification of specific topics covered in regional Internet portals, communities. It is necessary to monitor the attitude of users to state support programs and timely identify problems on the way to their effective implementation. Such monitoring can be carried out through the analysis of large text data—records and comments in the thematic communities of various social networks and thematic websites.

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Case Experience of the Formation and Development of AgroTech in Russia and Its Regions

Issues Related to the Implementation of Russian Regulatory Documents Harmonized with International Approaches Regarding Food Safety Control

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Abstract The paper relies on the review of academic literature and international and domestic regulatory documents to demonstrate that realization of the potential that is rooted in HACCP and ISO concepts is inadequate for the resolution of practical issues of the quality management of products of facilities of the foodservice industry. The goal of this paper is to explore the issues related to the implementation of Russian regulatory documents harmonized with international approaches regarding food safety control. The introduction of a new regulatory document that would regulate the Sanitary and Epidemiological Requirements to public catering arrangement in the Russian Federation contains the provision according to which catering facilities must exercise manufacturing control in line with HACCP principles. To assess the status of HACCP in the current practical activity of catering facilities, we conducted a questionnaire of their employees with secondary vocational education. The Questionnaires included questions to evaluate the activities of the managers of catering facilities aimed at the implementation of the HACCP system, as well as questions to evaluate the proficiency level of employees of catering facilities in the field of HACCP and ISO principles. The following was found: activities of the managers to implement the HACCP system were evaluated as poor (grand average score of 1.7) and that the managers of catering facilities failed to achieve an adequate level of food safety management. As can be seen from respondent responses, the proficiency

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_6

levels of employees of catering facilities according to the HACCP system were low (grand average score of 2.1). Likewise, low proficiency levels of employees were identified according to the ISO standard (grand average score of 2.2). All of this allows us to believe that the concept of risk-oriented thinking was not adopted by managerial and production personnel of catering facilities. Moreover, the analysis of questionnaire data brings us to the conclusion that the main problem for catering facilities consists in the low skill level of their managers. Recommendations for the introduction of HACCP and ISO systems in catering practices were formulated based on the research findings.

Keywords Catering · Food management · HACCP · ISO

JEL Codes L15 · L23 · L67 · L88 · M11 · M12 · N01 · N70 · L15 · L23 · L88 · M11 · M12 · N01

1 Introduction

By the early 1950s, William Edwards Deming was the first to introduce the quality management system that was based on his concept of continuous improvement of industrial products manufacture (Deming, 1986). The idea of the quality management system and organizational measures for the manufacture of quality products were subsequently used for the development of a new concept for food production. In the 60s of the past century, the HACCP concept was substantiated for the first time (hazard analysis and critical control points) for food production. The timeline of the development of the HACCP concept in professional literature was considered in detail (Ropkins & Beck, 2000).

The key milestones at the final stage of development and reduction to practice were as follows: 1983 (the use of the HACCP system was recommended by the WHO in Europe (Huss et al., 2003); 1985 (the International Commission on Microbiological Specifications for Food (ICMSF) was established, which contributed to the adoption of HACCP (Cronk, 1994); 1992 (seven underlying principles of HACCP were presented): 1993 (HACCP system based on hazard (risk) analysis in critical control points was included in the documents of international institutions (Weinroth et al., 2018). Therefore, by the early 1990s, it was a generally recognized fact that the implementation of the HACCP system is an efficient instrument for food safety control.

At the same time, an in-depth study of HACCP and cases of mass infectious diseases of the population of several Western countries in the 1990s to provide a reliable guarantee of food safety required the combination of HACCP principles with ISO 9000 principles, developed by the International Organization for Standardization (ISO) and not relating to food safety (Efstratiadis et al., 2000). Within this framework, the abovementioned international organisation adopted the second key international standard in 2005—ISO 22000 (ISO 22000-2005), which integrates the

HACCP system. After all, the global best practices of ensuring food safety in line with HACCP and ISO principles apply to all countries (Efstratiadis et al., 2000).

The recognition of the role of international instruments regarding food safety management in the Russian practise of ensuring the safety of food produced in the Russian Federation, as well as the introduction of instruments that are harmonized with international instruments, established a legal framework for the management of food quality according to Russian standards (GOST R 51705.1-2001; GOST R ISO 22000-2007). The significance of the introduction of GOST R ISO 22000-2007 is because this regulatory document establishes a system of generally recognized uniform requirements for food producers at all stages of their life cycle. This functional role of ISO is achieved because this document is based on the use of risk-oriented thinking aimed at food production using favourable opportunities and prevention of undesirable outcomes under the requirements of modern food safety management.

However, the introduction of regulatory requirements in the field of food safety management in the practical activity of catering facilities faced challenges that are associated with the human factor (Dimitriev et al., 2018, 2020; Efstratiadis et al., 2000; Weinroth et al., 2018). Due to the introduction of new sanitary regulations and standards in public catering arrangements, the issues related to the implementation of Russian regulatory documents harmonized with international approaches in catering facilities emerge full-blown.

The goal of this research is to study the issues related to the implementation of Russian regulatory documents harmonized with international approaches in catering facilities through the implementation of HACCP and ISO principles.

2 Materials and Methods

In this paper, we analysed scientific publications and regulatory documents and studied the implementation of HACCP and ISO principles according to Russian GOST standards (GOST R 51705.1-2001; GOST R ISO 22000-2007). The research was carried out through an analysis of answers in the questionnaire developed by the authors. The questions in the Questionnaire were drawn up using standard definitions as well as definitions from professional literature (Wallace et al., 2005).

Questions in the Questionnaire were answered by experts with secondary vocational education in the field of catering food production technology, who were the first-year and second-year extra-mural students in the speciality 19.03.04 “Catering food production technology and catering arrangement”. The number of persons involved in the survey was 98. When the survey was conducted, the students were not studying any management topics within specialist disciplines. Respondents evaluated the degree of the introduction of HACCP principles and methodology in the management teams of companies and decisions taken by the managers. Measures taken by the managers of catering facilities to implement the HACCP system were evaluated using the five-grade Likert scale (1—not started, 2—first steps were made,

3—positive results can be observed, 4—positive results are substantial and 5—the HACCP system was implemented. In addition, the proficiency level of employees of catering facilities in the field of food safety management was evaluated using HACCP principles as well as a five-grade scale (1—basic knowledge, 2—poor knowledge, 3—satisfactory knowledge, 4—good knowledge, 5—excellent knowledge). Evaluation of knowledge according to HACCP and ISO standards was performed based on the studies using the three-grade Likert scale (1—basic proficiency, 2—poor proficiency, 3—good proficiency).

3 Results

This section describes the results of the study of modern management in facilities of the foodservice industry which was carried out in three areas: determining the status of implementation of the HACCP system; evaluation of the proficiency level of employees of catering facilities according to the HACCP system and the level of understanding the provisions and requirements of the ISO standard.

The employees of catering facilities who participated in our research had secondary vocational education and average employment experience in the same occupation of 2–3 years. Respondents were filling in questionnaires without indication of their surname, company name and street address (respondent's sex, age and education were specified in each questionnaire, as well as the name of territory where the company is located).

Data on the implementation of the HACCP system were collected and analysed based on answers of personnel of catering facilities are presented in Table 1, in which activities of the managers of catering facilities aimed at implementing the regulatory requirements for certain aspects of the implementation of the HACCP system were evaluated using the Likert scale.

As can be seen from data in Table 1, according to respondents, the managers did not take any substantial measures to meet regulatory requirements for the implementation of the HACCP system in the practical activity of their catering facilities (1.3 points). At the same time, from the reports of respondents, it follows that the goals of meeting the catering food safety requirements were defined at a much higher level (2.7 points). However, this result is merely indicative of the fact that the managers of catering facilities failed to achieve an adequate level of food safety management.

Since the degree of development of document management measures in the HACCP system is an essential condition for maintaining efficient operation of the catering food safety management system, the level of document management (1.4 points) implemented in catering facilities is indicative of a poor contribution of the managers in the implementation of HACCP principles.

As for the question about the degree of development of the company's product quality policy, respondents have a higher mark (2.3 points). This aspect of the evaluation of activities of the managers of catering facilities by employees was perceptible,

Table 1 Evaluation of measures taken by the managers of catering facilities for the implementation of the HACCP system

No.	Questions on the implementation of HACCP	Score*
1	Obligations of the managers of catering facilities in terms of operation of the HACCP system were defined	1.3
2	Goals of meeting the catering food safety requirements were defined	2.7
3	The document management procedure was developed to maintain the catering food safety management system	1.4
4	The catering food safety management policy was developed	2.3
5	The HACCP group was established	0.8
6	Personnel has fundamental knowledge of the catering food safety management system	1.1
7	Specifications for each catering food item were compiled	2.5
8	Laws and regulations, regulatory and technical documents in the foodservice industry were updated	2.0
9	Requirements of laws and regulations and regulatory documents were identified for them to be included in the programmes of mandatory preliminaries	1.9
10	Critical control points were identified and the monitoring system was developed	1.2
11	The catering products tracking system is documented	3.5
12	Internal audits of the HACCP system were conducted	0.3
Grand average score		1.7

* In the implementation of HACCP principles, the maximum score for an answer is 5 points
Source Developed by the authors

yet it cannot be positively evaluated, since the result of activities in this area in the implementation of HACCP principles must be evaluated at a five-grade level).

Organizational aspects of HACCP turned out to be a weak link in the activities of the managers. This is proved by the data on the evaluation of activities of the managers as well as other aspects of supporting the food safety management. Thus, in terms of formedness of HACCP groups, in terms of fundamental proficiency of personnel in the food safety management system, in terms of maintenance of documents in the foodservice industry, in terms of identification of critical control points and degree of development of the system of monitoring and internal audits of the HACCP system, average activity scores were ranging from 0.3 to 2.0 points.

Respondents' answers on the compilation of specifications for each food item (an average score of 2.5) are indicative of the fact that several companies have made significant yet insufficient steps in this direction.

While pointing out inadequate activities of the managers to hold the internal audit of the HACCP system (0.3 points), it may be noted that the presence of feedback is an indicator of efficient operation for any system. From this point of view, internal

audit is at the same time an indicator of extremely poor development of the HACCP system in catering facilities. Accordingly, the most important link in the HACCP system of catering facilities requires updating.

Hence, the data reviewed can be used to conclude that the managers of catering facilities failed to achieve a proper result in food production management in line with applicable regulatory documents regarding catering arrangement on none of the considered items of measures for the implementation of HACCP principles.

Following the target goal, studies were also carried out to evaluate the proficiency level of employees of catering facilities according to the HACCP system. Since the HACCP system is based on risk-oriented thinking, the efficiency of the implementation of the HACCP plan in a business environment depends on the knowledge and skills of the HACCP group and the entire production personnel regarding potential risks and their minimization in particular production processes. Accordingly, Questionnaires included 19 pivotal questions about the HACCP system and the answers to these questions are presented in Table 2.

Judging from the fact that the ISO standard implemented the concept of risk-oriented thinking based on HACCP principles with a specific definition of the content of preliminary stages as well as stages of development and implementation of the HACCP plan, we see it fit to evaluate personnel's proficiency level according to the ISO standard. To increase the proficiency level of employees, a special Questionnaire was used which included questions that were formulated in the language of the ISO standard: 1. What does a process approach that includes the cycle "Plan - Do - Check - Act" (PDCA) mean in the ISO standard? 2. What does the term "risk-oriented thinking" mean according to the ISO standard? 3. What are the benefits of the implementation of the food safety management system (FSMS) based on the ISO standard? 4. What generally recognized key elements are included in the FSMS according to the ISO standard? 5. What other essential principles of FSMS serve as a basis for the ISO standard? 6. What principles serve as a basis for the implementation of the concept of risk-oriented thinking in the ISO standard? 7. What general term can be used to describe the first 5 stages in Table A.1 of the ISO standard?

From the analysis of data obtained, it follows that the proficiency level of employees in terms of provision of the ISO standard was evaluated in the range of 0.7 to 2.8 points using the questions in the Questionnaires. That said, higher grade values were obtained for answers to questions "What does a process approach that includes the cycle "Plan - Do - Check - Act" (PDCA) mean in the ISO standard?" (2.1 points), "What does the term "risk-oriented thinking" mean according to the ISO standard?" (2.8 points) and "What generally recognized key elements are included in the FSMS according to the ISO standard?" (2.5 points). Other questions in the Questionnaire produced much lower scores of the proficiency level of personnel of catering facilities—0.7 to 0.9 points. In this case, the grand average score was 2.1. Hence, respondents' knowledge of ISO provisions turned out to be lower than the maximum grade (3 points).

Table 2 Evaluation of the proficiency level of employees of catering facilities according to the HACCP system

No.	Questions on HACCP	Score*
1	Please explain, what does hazard (risk) mean?	1.8
2	Please explain, what do critical limits mean?	0.8
3	What is the purpose of the flow chart in HACCP?	1.2
4	Why is it important to verify the flow chart in the workplace?	1.1
5	What is a critical control point (CCP)?	2.5
6	How can CCPs be verified?	1.8
7	Please specify the preliminary steps (measures) before the development of the HACCP plan	0.7
8	Monitoring procedure—what kind of activity is that?	2.4
9	What figures are most often used in the monitoring procedure in CCP?	2.3
10	Please specify HACCP principles	3.2
11	In what cases are corrective actions required?	4.2
12	What records are made following the monitoring procedure?	2.7
13	Why is microbiological testing not included in the monitoring procedure?	0.5
14	Why is microbiological testing the most expedient instrument for the verification of the HACCP system?	0.8
15	Why is it important that the development of the HACCP plan is performed by a team of experts with different specialization profiles?	3.2
16	What final document is being drawn up by the HACCP group?	4.1
17	Please specify two verification procedures confirming that the HACCP system is functioning properly	1.4
18	In which cases does the HACCP system update itself?	2.7
19	What is the frequency of audits of the HACCP system?	3.8
Grand average score		2.1

* In the evaluation of the proficiency level according to the HACCP system, the maximum score for an answer is 5 points

Source Developed by the authors

4 Discussion

The history of the development of HACCP and ISO principles in the countries that were pioneers in terms of regulatory and legislative formalisation of the modern

food safety management is indicative of the fact that the implementation and maintenance of the quality management system is a universal mechanism of providing the guarantee of food quality (Weinroth et al., 2018).

Implementation of Russian regulatory documents harmonized with international approaches regarding food safety control is a critical state problem in the Russian Federation. Russian legislative and regulatory framework regarding food safety management generally establishes a system of requirements for the implementation of the HACCP system (GOST R 51705.1-2001; GOST R ISO 22000-2007; SanPiN 2.3/2.4.3590-20; TR CU, 2011). However, many domestic authors point out that the issues of implementation of the HACCP system are poorly resolved in the catering system (Chernukha & Khvorova, 2012).

Our survey showed that the managers of catering facilities do not ensure practical application of the key regulatory requirements of HACCP principles. The studies of this problem by other authors are also indicative of a low level of implementation of principles of the modern food safety management of facilities of the foodservice industry (Chernukha & Khvorova, 2012). These data on the poor implementation of the HACCP system demonstrate insufficient responsibility of the managers of catering facilities for the achievement of high hygiene standards and legislation enforcement. This situation can be changed under certain conditions, which should primarily include meeting the requirements that were imposed on catering facilities by the state during their licensing. These conditions should include certification of products, meeting the sanitary and epidemiological requirements to the provision of catering services. In the present context, catering facilities are focused on the sales of products without the provision of services for the arrangement of acceptance of food; that said they must certify their products (GOST R ISO 22000-2007).

Research for the evaluation of the proficiency level in the field of HACCP and ISO revealed poor awareness of the issue under consideration with personnel of catering facilities. Other researchers who were considering the level of preparation to practical activities on the implementation of the HACCP system, arrived at similar conclusions (Chernukha & Khvorova, 2012). Foreign authors point to the fact that education and training lie at the heart of the implementation of the HACCP system (Ropkins & Beck, 2000; Wallace et al., 2005).

The main obstacles on the path towards the implementation of the HACCP system in our country still consist in the lack of guidance papers harmonized for practical application, the lack of master's degree with the managers of catering facilities, the lack of motivation to implement HACCP principles, the lack of specialized centres for training personnel of catering facilities, and other factors.

The assessment of efficiency of the implemented HACCP system is still poorly elaborated and substantiated as well. In the meantime, the data in this publication and the data from other authors (Soon et al., 2012) are indicative of the need for the scientific substantiation of criteria for assessing the food quality management in catering facilities.

The data on the evaluation of knowledge according to the ISO standard, which has identified poor proficiency of personnel of catering facilities lead us to the conclusion that the implementation of HACCP principles within the scope of the ISO standard

open up a new opportunity for tracking the connection between source raw material, ingredients and intermediate products with the final product, and for implementing preliminary measures before the development of the HACCP plan.

Hence, the performance of duties that are imposed on the managers of catering facilities in compliance with regulatory documents will be the execution of professional duty in catering by the managers of catering facilities.

5 Conclusion

The review of international and domestic literature presented in the Introduction section shows that the development of the HACCP concept and their recognition by influential international authorities resulted in the formation of a document management system regarding food safety management at the international level. The paper discusses the issues related to the implementation of Russian regulatory documents harmonized with international approaches in catering facilities, as well as own research results. Research data allow us to point out that the managers of catering facilities are poorly motivated for the implementation of HACCP principles. This situation results in poor proficiency of personnel in the field of HACCP and ISO principles. The paper discusses the issues of overcoming obstacles on the path of the implementation of the HACCP system in our country.

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Prerequisites for the Administrative Reform of Rural Areas (on the Example of the Republic of Bashkortostan)

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Abstract *The purpose of the article* is to substantiate the necessity and determine the directions of the administrative reform of the rural areas of the republic. *Methodology/Approach*: The authors use comparative analysis methods based on data from the Federal State Statistics Service. *Results*: it was found that in recent years there has been a narrowing of the area of authority of municipalities, there is a tendency to increase the number of public sector workers, which determines the costs of maintaining the staff of rural administrations. The creation of electoral districts by combining municipalities or their parts entails certain difficulties in the conducting of elections and the work of elected deputies. However, the enlargement of municipalities can have a positive effect in the form of a reduction in the number of deputies and an increase in their activity, the creation of a more efficient system of interconnection between the centre and municipalities, the authorities and the population. Changes are also required in the management system at the settlement level. The proposals of several regions to refuse to create councils in rural settlements, according to the authors, will have a positive effect, however, they require analysis and, if they are accepted, adaptations taking into account the conditions of the republic. The analysis shows that the changes taking place in the administration of rural areas are mostly positive and focused on new conditions for the work of government bodies. These changes should form the basis for the reconstruction of the municipalities' structure. *Originality*: the study has shown that there are serious prerequisites for the administrative reform of rural settlements. At the same time, reforms can carry certain social

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_7

risks, which require taking them into account and introducing measures to minimize their impact.

Keywords Administrative reform · Rural areas · Municipalities

JEL Codes H70 · R10 · R58

1 Introduction

The relevance of the work is determined by the peculiarities of the administrative-territorial division in the Republic of Bashkortostan. A two-level system of municipalities has developed in the republic. The first level includes urban districts (including the closed city of Mezhgorye) and municipal districts, the second level—urban and rural settlements. There are 895 municipalities in total, 9 urban districts, 54 municipal districts, 14 urban settlements, and 818 rural settlements. Within this two-level system, 21 cities function, of which 9 have the status of urban districts, 12 are urban settlements, and two industrial communities (Priyutovo and Chishmy) have the status of an urban settlement (Paradoxes and prospects …, 2012). According to the data of census, there are 4,532 villages and hamlets in the republic, which are part of 818 rural settlements and are geographically united into 54 municipal districts (Population of the Republic …, 2013). In total, since November 1, 2018, there are 895 municipalities in the republic, which is 4.0% of the total number of municipalities of the Russian Federation (Regions of Russia, 2020).

In terms of the number of municipalities (*urban districts, municipal districts, urban and rural settlements*), the Republic of Bashkortostan ranks 2nd place in the Russian Federation after the Republic of Tatarstan, and it is also in 2nd place in terms of the number of municipal districts (Altay Territory—1st). In terms of the number of urban districts (the largest cities Ufa, Sterlitamak, Salavat, Neftekamsk, Oktyabrsky, Beloretsk), the republic is in 15th place (Socio-economic situation …, 2020).

The municipal districts of the republic are characterized by an uneven number of rural settlements in their quantity: from 9 units (*Kiginsky District*) to 22 (*Baymaksky and Ilishevsky Districts*), and in the rural settlements of municipal districts there are from 1 to 25 settlements (*rural settlement Michurinsky village council municipal district, Sharansky District*) (Socio-economic situation …, 2020).

Rural settlements account for 92.0% of the total number of municipalities of the Republic of Bashkortostan. Attention is drawn to the number of indicators: the majority of rural settlements are settlements with a population of fewer than 1,000 people (Socio-economic situation …, 2020).

In our opinion, the existing and not reformed territorial infrastructure is moving to the level of failures and requires immediate strategic regulation of all its subsystems, the entire complex of interconnected service structures or objects that make up and provide the basis for the functioning of the system (Preliminary concept of …, 2018). The need for reform determines the relevance of this work.

2 Materials and Methods

The main indicators of the activities of local self-government bodies of the republic are the growth rates of tax and non-tax revenues, land relations, the development of utility infrastructure and measures for the improvement and sanitary cleaning of settlements, the creation of jobs and the level of unemployment, the solution of social issues and the development of the social and political activity of the population (Decree of the Head …, 2016; Decree of the President …, 2008). To solve these problems, the necessary measures are being taken to attract investments in the economy of municipalities. According to the analysis of the investment activity of the republic's municipalities, the largest share in the total volume of investments was formed by the cities of Ufa, Salavat, Sterlitamak, Neftekamsk, as well as the Ufa Region. These territories form about 70.0% of the total investment in the republic.

A comparative analysis of the Republic of Bashkortostan with neighbouring regions-subjects of the Russian Federation, as well as other regions-subjects of the Volga Federal District, shows that the republic has one of the largest territories (142.9 thousand m^2), second only to the Sverdlovsk Region (194, 3 thousand m^2) and the Perm Territory (160.2 thousand m^2). In terms of population, which is more than 4 million people, Bashkortostan is in 2nd place, after the Sverdlovsk Region (more than 4.3 million people). At the same time, the republic has a relatively low population density, which is just over 28 people per 1 km^2 (11th place among the considered regions-subjects) (Regions of Russia, 2020).

Although, as noted above, Bashkortostan is in 3rd place in terms of the area of its territory, nevertheless, in terms of the area per municipality, it corresponds only to the 6th place among the analyzed regions-subjects.

With the ratio of the population to the number of municipalities (in the context of municipal districts and urban districts), the following are clearly distinguished: the Republic of Tatarstan, Samara and Chelyabinsk Regions. In Bashkortostan, one municipal formation accounts for about 64.5 thousand people, for comparison: on average, for the considered regions, this number is slightly more than 56 thousand people (Regions of Russia, 2020).

If we compare the population living only in rural municipal districts with the number of the latter, then Bashkortostan is inferior in this indicator to Tatarstan, where on average one municipal district accounts for almost 50 thousand people, and the Saratov Region, where the same indicator is slightly more than 42 thousand people (Regions of Russia, 2020).

The number of employees in local government bodies is quite large in the Republic of Bashkortostan, which exceeds 11 thousand people, which corresponds to the 3rd place after the Nizhny Novgorod (almost 14 thousand people) and Chelyabinsk (more than 13 thousand people) Regions. For example, in regions that are approximately comparable in terms of population and rather highly developed regions, such as the Republic of Tatarstan and the Sverdlovsk Region, their numbers are significantly lower and amount to 8.7 and 8.4 thousand people, respectively (Regions of Russia, 2020).

In terms of the number of employees in government bodies in the Moscow Region, per one municipal entity in the context of municipal districts and urban districts, Bashkortostan occupies a middle position (8th place). Therefore, the republic has the potential to reduce this indicator from 181 people per one municipality, for example, up to the level of the Sverdlovsk Region—116 people per municipality (Regions of Russia, 2020).

Thus, for the Republic of Bashkortostan, the problem is of high urgency and there is a potential for renewing the structure of municipalities.

3 Results and Discussion

The existing administrative division of the Republic of Bashkortostan into municipalities has not been changed over the past 50 years. Naturally, during this time, a large number of problems have accumulated in this structure, and these problems generally do not take into account the new realities, existing and emerging economic ties, the real directions of internal migration flows, and the development of human potential in specific regions. There is every reason to state that the region is significantly lagging in resolving this issue: across the country, the processes of the consolidation of federal bodies with the creation of large inter-district formations and centres (tax services, supervision services, some life support services, etc.) are at the stage of completion. Demographic failures, changes in the age pattern of the population also affect the prospects for the development of municipalities.

Currently, there is a narrowing of the area of authority of municipalities, when the dominant directions in their activities are only the social sphere (education, culture, etc.), while traditionally developed areas (agriculture) are leaving the area of responsibility of district administrations. Despite the ongoing measures to reduce the number of public sector workers, there is a trend towards their increase, which causes a permanent increase in the cost of maintaining the staff of rural administrations.

A problem should be recognized in the situation when, in order to ensure an equal number of electors in the republic, electoral districts are created that unite several municipalities or a part of them. In turn, this leads to organizational difficulties during the preparation and conducting of elections, to the disorganization of the work of the elected deputies with the population in the districts.

The existing management system at the settlement level requires analysis and revision. In several regions of the Russian Federation, thoughts are rising about abandoning the creation of councils in rural settlements, which positively solves two tasks: first, the status and role of heads of rural settlements are becoming more active; secondly, the difficult issue of organizing elections and recruiting personnel for work in local councils is removed from the agenda. Such proposals from the regions of Russia require analysis and in case of a positive assessment—adaptation within the republic (Gataullin et al., 2017).

An analysis of the situation shows that the new realities that have arisen in this area are mostly positive and focused on new conditions for the work of governing bodies.

Among such realities that have necessitated renewal (reform) and which should form the basis for the reconstruction of the structure of municipalities, the following can additionally be attributed:

– development and continuously expanding communication system, covering almost the entire territory of the republic in the form of uninterrupted telephone communication with the participation of large operators, the presence of a stable Internet;
– almost entire coverage of the territory by television and radio communication networks, which allows round-the-clock and instant access to information for the consumer;
– availability of stable road connection, mainly with a hard surface, that meets modern requirements;
– expansion of the fleet of personal individual motor vehicles and the possibilities of its maintenance and provision of fuel and lubricants;
– the presence of a developed network of public transport, which, with the reasonable operation and compliance with the principle of legality, can become an option for a more cost-effective replacement of the individual vehicles use;
– the integrity of the system of traditional methods of transferring information and the communication network (Russian post, courier service, participation of various operators in organizing the transportation of goods, etc.);
– the presence of stable directions of the population flows movement worked out over the years, taking into account the time of the year (seasonality), of the week (beginning and end), routes for obtaining medical care (hamlet, village—regional centre, city, capital), bilateral and multilateral directions of recreation (village—city, city—village, republic—other regions, republic—other countries);
– the creation of state institutions, around which the labour, educational, and recreational spheres of municipalities are concentrated (construction of infrastructure facilities in the form of health resorts, etc., the emergence of enlarged middle-level educational centres, etc.);
– the enlargement of educational institutions of preschool and general education, the reason for which was the decrease in the number of children, the creation of basic educational institutions of general education with the strengthening of their material, technical and information base;
– reorganization of the network of consumer and commercial services to the population towards a total replacement of the public sector by the private sector;
– enlargement of medical institutions (FASs) and cultural services (clubs, libraries) with their concentration in large settlements;
– It should be pointed out that there is a gradual fading of life in individual municipalities. That is:
– a decrease in the number of the rural population, which in the age group becomes threatening, the emergence of "demographic scissors" with a predominance of the elderly population (the so-called "population ageing" process);
– migration flows (pendulous: in the morning—to work, in the evening—home; seasonal: departure to work for a certain time, etc.);

– a decrease in the number of school graduates, whose number is reduced to 3–4 grades, and a decrease in the number of children entering the first grade;
– the displacement of traditional types of agricultural and other activities due to the lack of sales markets, the desire to work;
– growing drunkenness in rural areas and the criminalization of various aspects of life;
– change of the positive mentality traditionally inherent in the rural population towards a welfare mentality.

This is only a part of the negative prerequisites, which are also a force conducive to the search for new schemes of territorial structure.

4 Conclusions

The study makes it possible to draw some conclusions that are important for the regions. The new realities have both positive and negative connotations and directly indicate the need for rapid reforms in order to begin to implement the tasks ahead.

Administrative reforms affecting the traditional way of life in most regions of the Republic of Bashkortostan must be classified as phenomena with increased content of social risks. The organization of such a very complex work should be carried out taking into account possible risks and should provide for measures to minimize their impact. Among the main risks are the following.

The emergence and accumulation of protest moods among the population, which may spill out in the form of various actions and appeals (rallies, complaints to various authorities, etc.). As always, active carriers of such sentiments can be people of the older generation, part of the youth, fueled by arguments of a false patriotic sense, and people who are in a cohort of fringes of society (the unemployed, homeless people, etc.). It is necessary to oppose the protest moods with motivational goals and objectives of the socio-economic development of new municipalities, in particular, clarification of the content and directions of the Strategy for the socio-economic development of regions and strategies for the development of municipalities.

An untimely explanation of the reasons or their complete absence can result in a sharp increase in appeals and complaints to various authorities regarding changes in the boundaries of municipalities. Therefore, this process should be accompanied by a discussion of the problem at the level of various residents' meetings, in production collectives, speeches by elders and respected people from the area. To this end, special television programs with the participation of historians, political scientists, economists and managers can be useful. In this sense, it is necessary to study the development of the border problem in the regions of Russia, for example, in Ingushetia.

The protest movement can result in ignoring mass socially significant events, primarily such as elections at all levels. The basis of such movements can be inadequate actions of representatives of local authorities, leaders of social movements at

the local level, religious clerics. Taking into account the fact that when defining the boundaries of districts in the 30 s of the last century, they proceeded from the tasks of administration, not taking into account today's economic and social realities, which requires clarification to the people. They should be aimed at showing the economic inconsistency of continuing the old scheme of division of areas and that the new layout can bring strong economic effect.

At the same time, it is necessary to prepare a new scheme for defining the boundaries of rural generations, to prepare normative legal acts to change the status of heads of rural settlements towards strengthening their powers, defining the functional responsibilities of law enforcement officials, expanding the circle of influence of educational and cultural authorities. Ideally, rural settlements should be allowed to accelerate the development of those areas in their life, which: (a) historically formed or conditioned; (b) have taken shape in recent years in a new situation of the development of the country, region, district, village; (c) are offered by well-known natives, elders; (d) offered by representatives of science.

A widespread mistake of power structures (especially at the municipal level) is the inability to predict the situation in districts and rural settlements, the inability to draw up a list of countermeasures to mitigate possible negative phenomena. Neutralization of this risk and its impact on the manageability of territories consists in the preparation of strategies for the development of municipalities, taking into account the Strategy of socio-economic development of the Republic of Bashkortostan, ensuring a unified style in setting goals and objectives, in determining the final results and indicators that allow setting goals.

Difficulties in management are expected to be the first due to the increase in the size of the territory of the municipality, as a result of this, a decrease in the efficiency of management.

To overcome this risk, it is necessary to implement large-scale and economically rational projects and activities that will take into account the development priorities of the region's economic zones and inter-municipal effects. Municipal staff will need to be more qualified. The financial base will expand by reducing the cost of maintaining local self-government bodies. At present, budgetary funds are "scattered" across municipal districts; they cannot be concentrated to carry out primary, but spending work (Prokhorova, 2013). In the united administration, fewer funds will be required for the maintenance of the administrative apparatus, since the number of rates will decrease (The head of the administration …, 2019). For example, instead of several chapters, one chapter will be elected, instead of dozens of accountants, economists duplicating each other, several will be enough. The principle of economic rationale should be dominant. In other words, municipalities should, first of all, exist where there are economic centres: industrial, transport and logistics centres, agricultural enterprises, zones of promising development (Sabyna, 2016).

Reducing the availability of services provided by local governments, municipal enterprises and institutions for residents of remote rural settlements. The deterioration in the quality of state and municipal services provided to citizens can affect the level and quality of life and, ultimately, provoke the departure of residents from rural areas (Gutnikova, 2010).

To neutralize this risk, only specialists must remain to work in each locality where there is currently an administration. As before, on the ground, rural residents will be able to obtain the necessary information, assist in paperwork, and resolve other issues that are now being dealt with by rural administrations.

The specialists who remain in the field will directly work only with people, and not be engaged in the development of regulations, preparation of responses, reports to various structures, which currently consume the bulk of their working time.

Separation of the population from the municipal administration. It is more difficult for the population to take part in the life of the municipality in the process of territorial administration.

Overcoming risks in this area can go along the following path. Expansion of the MFC network, electronic document management will save time for working with lots of people. On the other hand, it will be possible to elect a new generation of professionals for the positions of heads of the united administrations, who will be caring, active, responsible, who will work taking into account the opinions of the citizens of each territory, their task in relying on modern info-communication technologies will be so that the population does not feel that the power has "moved away".

Administrative reform should be accompanied by the intensification of legislative activity. The main regulatory documents governing the process of life of local self-government in the Republic of Bashkortostan are the Constitution of the Russian Federation, the Constitution of the Republic of Bashkortostan, the Federal Law "On General Principles of Organization of Local Self-Government in the Russian Federation", the Law of the Republic of Bashkortostan "On Local Self-Government in the Republic of Bashkortostan" (Law of the Republic …, 2015). The directions of the administrative reform, one way or another, will require amendments to these documents.

Summing up, we can say that the above proposals are largely provisional (preliminary) in nature and require additional study of the problem. In particular, this concerns the issue of economic alignment of the potentials of the united municipalities, the issue of levelling the problems of the borders of the newly created enlarged municipal districts.

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Development of Digital Regional Ecosystems: Russian Specifics and Risk Leveling

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Abstract The article aims at studying the Russian specifics of the development of digital regional ecosystems, as well as analyzing risk factors and designing effective tools for levelling them. The authors propose to use a subject-infrastructure approach to the study of digital regional ecosystems. This allowed the authors to present the digital regional ecosystem as a unity of interacting entities (citizens, business, scientific and educational community, state), their abilities and capabilities to use data in digital form as a special type of factors of production, as well as the environment of their interaction formed by digital infrastructure and mechanisms for integrating technological solutions within the established institutional field. The authors propose a model for assessing the state of a digital regional ecosystem in terms of a subject-infrastructure approach, including the stages of structuring a digital regional ecosystem; selecting indicators to assess the state of a digital regional ecosystem and calculation of integral indicators; analyzing risk factors for the development of a digital regional ecosystem; determining directions for improving the digital regional ecosystem based on levelling risk factors. The proposed model was tested on the example of five regions of Russia and confirmed the assumption about the differentiation of the development of digital ecosystems in different regions. The results

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_8

obtained by the authors can be used by executive authorities to improve management decisions on the development of regional digital ecosystems.

Keywords Digital regional ecosystem · Region · Risk factors · Russia · Digitalization · Digitalization of subjects · Digital infrastructure

JEL Codes O33 · R11

1 Introduction

Change is all around us. Despite new challenges in the form of slowing economic growth in most countries and the COVID-19 pandemic, the development of digital technologies is taking leaps and bounds. It was digital technologies that became the very tool that provided opportunities for the implementation of activities and interaction of people in conditions of quarantine restrictions and lockdown in 2020. Artificial intelligence, big data and robotics technologies have been used for medical purposes to help seriously ill people, to educate the population, and to implement life support functions during social distancing (Karpunina et al., 2020). However, the digital development of countries and their regions is extremely differentiated. And the pandemic has highlighted its weak elements. For example, it was possible to see how easily the residents of megacities coped during the lockdown period, using Internet technologies in their daily routine, and how hard quarantine restrictions were given to the population of remote regions of Russia (Korolyuk et al., 2021).

Public authorities at all levels have revised approaches to the digitalization of regions and adapted the experience of the country's leading regions in the field of digital development. In particular, the so-called ecosystem approach to regional governance has proved its effectiveness in Russia within the framework of the project "State as a Platform" (Center for Strategic Research, 2018; O'Reilly, 2011). Examples of its implementation are the introduction of concepts for the development of intelligent digital technologies and the reindustrialization of the economy "Smart region", in particular, in the Ulyanovsk, Novosibirsk and Sverdlovsk Regions (Lyshchikova, 2020).

Currently, new measures are being taken to ensure digitalization. However, the improvement of existing approaches in this regard deserves special attention.

2 Literature Review

The traditional understanding of the digital ecosystem is connected with the interaction of technological platforms, online services and analytical systems of various organizations, information systems of public authorities and citizens (Karpunina et al., 2020). The basis of the digital ecosystem consists of interacting entities that

exchange digital resources and transform some of their types into others (Apokin et al., 2015). Some researchers argue that the success of the digitalization of the state depends on their effective interaction (Karpunina et al., 2020). This is the position of representatives of the so-called subjective approach to the study of digital ecosystems. Other scientists assign a dominant role to the architecture of the digital ecosystem (a combination of horizontal and vertical integration of technological solutions), proving that it provides intensive digital development of various sectors of the economy (Lyshchikova, 2020; Stepanova et al., 2019). This view is typical for representatives of the infrastructure approach.

The effectiveness of the functioning of the digital ecosystem of the state depends on the development of digital regional ecosystems. However, the methodology for assessing their effectiveness still requires improvement (Akatkin et al., 2017; Esaulov, 2017; Henfridsson & Bygstad, 2013; Karyshev, 2011; Plaksin et al., 2017).

In countries with a low level of digitalization, the development of digital regional ecosystems may be hindered by permanently emerging risks associated, in particular, with the quality of regional digital infrastructure, low level of digital literacy, insufficient financing of implemented digital programs and projects (Bychkova et al., 2020; Samorodova et al., 2019).

3 Methodology

The purpose of the study is to highlight the Russian specifics of digital regional ecosystems, systematize the risks associated with their development, and also offer effective tools for levelling the risks of the external and internal environment.

Research objectives:

- to reveal the conceptual foundations of the functioning of the digital regional ecosystem;
- to create a model for assessing the digital regional ecosystem following the subject-infrastructure approach;
- to make a comparative assessment of the state of digital ecosystems of Russian regions, as well as to identify the risks of long-term development;
- propose measures to mitigate the risks of developing a digital regional ecosystem.

Research methods: the method of theoretical analysis, the method of systematization, the method of economic analysis, the method of integral indicators, analysis and synthesis.

4 Results

Let's take as a basis the understanding of the digital regional ecosystem presented in the studies of Lyschikova (2020) and Stepanova et al. (2019).

Lyschikova (2020) extrapolates the specifics of the business ecosystem as a network structure to the level of regional management and offers a promising structure of the digital regional ecosystem:

- digital platform as the core of the region's ecosystem;
- multi-agent regional community, including regional authorities (organizers of the digital platform), independent developers and providers, end-users (residents of the region);
- architecture of the digital regional ecosystem (combination of horizontal and vertical integration of technological solutions);
- institutional foundations for the functioning and development of the digital regional ecosystem (Markova, 2018).

Stepanova et al. (2019) adhere to a different approach to structuring elements of digital regional ecosystems. In particular, the authors identify the subjects of digitalization interacting in the digital ecosystem (business, population and regional government bodies), as well as the so-called digital habitat (6 most important conditions for the existence of the digital economy and digital society in the region).

Researchers refer to the digital habitat as:

- digital infrastructure: the creation of a unified telecommunications system for the digitalization of the telephone network and providing access to the broadband Internet for all stakeholders;
- digital competencies of the population: individuals' skills in using computer technology, the Internet and digital technologies for personal and professional purposes;
- digital education: digital educational programs provided by the higher education system, implemented in the presence of a formed material and technical base;
- spatial and territorial structure: concentration of technological, information and intellectual resources, depending on the level of urbanization and development of the territory;
- science and innovation: the level of their development in the region is determined by the available research competencies and technical reserves;
- availability of resources: energy resources that ensure the operation of computer equipment and digital platforms, as well as financial resources that determine the possibilities of creating digital infrastructure, updating digital equipment, training highly qualified personnel.

In our opinion, with regard to the regional level and taking into account the imperfection of (HSE, 2019; Federal State Statistics Service, HSE, 2020) information reflecting the processes of digitalization of territories, it would be optimal to use a subject-infrastructure approach to assessing the state of digital regional ecosystems (Fig. 1).

The digital regional ecosystem can be represented as a unity of:

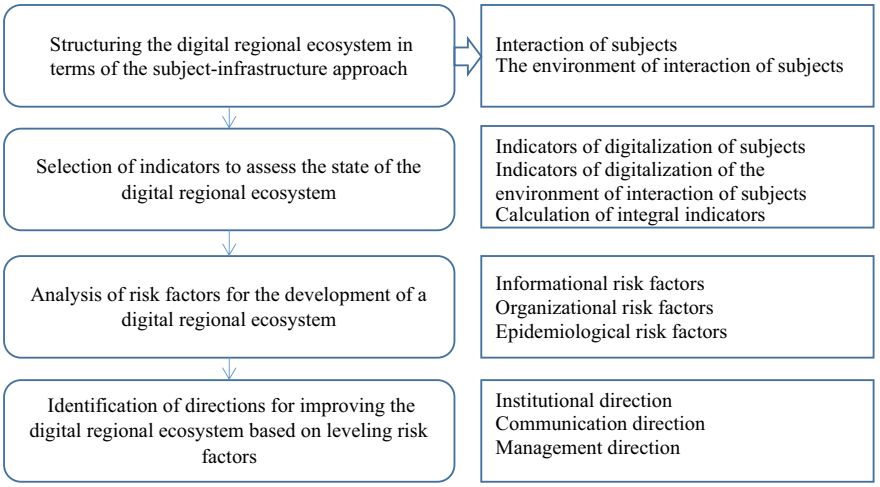

Fig. 1 A model for assessing the state of the digital regional ecosystem. *Source* Compiled by the authors based on the data of Figshare Repository (2019)

- interacting entities (citizens, business, scientific and educational community, state), their abilities and capabilities to use data in digital form as a special type of factors of production;
- the environment of their interaction is formed by the digital infrastructure (the spread of broadband Internet, the use of information and communication technologies, local networks, servers, etc.), as well as mechanisms for integrating technological solutions within the established institutional field (Kramin & Klimanova, 2019).

The first structural component reflects the subject approach to the study of digital regional ecosystems, the second component provides an assessment of the external and internal space of interaction of subjects, creating an environment for the digitalization of the economy and society in the region.

It is possible to define a system of indicators to evaluate each component based on the proposed structure of the digital regional ecosystem.

To analyze the selected indicators, it is advisable to use the method of calculating integral indicators (Molchan et al., 2022; Vasilyeva, 2017). The method involves comparing the regions for each indicator (X_i) with the region with the best results for the selected indicators (X_{max}), as well as their subsequent ranking and standardization using formulas 1 and 2.

$$xi = Xi/Xmax \tag{1}$$

$$I = \sqrt{\sum_{1}^{i}(1 - xi)^{2}}, \tag{2}$$

where x_i—standardized indicators reflecting the state of the digital regional ecosystem, $i = 1 \ldots$. n.

The evaluation of the digitalization of interacting subjects is based on the calculation of an integral indicator I_s (n = 13). The assessment of the level of digitalization of the environment of the interaction of subjects is carried out using the integral indicator I_e (n = 5). The rating score according to the consolidated integral indicator of the state of the digital regional ecosystem (I_c) is determined by the method of the sum of places according to the formula 3:

$$Ic = \sum_{1}^{i} vi * Ii \tag{3}$$

where v_i—the coefficient of the significance of the i-th indicator obtained using the method of expert assessments.

The application of the proposed methodology is carried out on the example of several regions of Russia: Voronezh Region, Lipetsk Region, Tver Region, Krasnodar Territory and the federal city of St. Petersburg.

All the initial data and calculations of integral indicators of the digital regional ecosystem are presented in Table 1 of the Figshare Repository (2019).

The authors calculated three integral indicators for each of the five regions of Russia based on the data in Table 1 of the Figshare Repository (2019).

The best region among the analyzed regions according to the state of the digital regional ecosystem is the federal city of St. Petersburg, it leads both in the digitalization of interaction of subjects and in the state of the formed environment of the interaction of subjects of the digital regional ecosystem. The Krasnodar Territory occupies the second position among the analyzed regions, but it has a stronger position in terms of digital infrastructure and the mechanisms used to integrate technological solutions, that is, in terms of the second integral indicator. The Voronezh Region takes third place in the rating, demonstrating the high quality of digitalization of interacting subjects. The weakest development of the digital regional ecosystem was shown by the Tver Region, which took fifth place in the rating for all three integral indicators (Federal State Statistics Service of the Russian Federation, 2020).

The range of variation of the consolidated integral indicator of the state of the digital regional ecosystem is 0.8293. This confirms the authors' assumption about the existence of a significant level of development of digital ecosystems of the analyzed regions of Russia.

The next stage of assessing the state of the digital regional ecosystem is the analysis of risk factors for its development. Information risk factors are caused by the inconsistency of the information structure of existing organizational networks and the digital regional ecosystem, the imperfection of regulation of interdepartmental interaction at the regional level, as well as the lack of structured information, flows that determine the activities of complex network partner structures in regional

management. In particular, the procedure of entrepreneurial search for "smart specialization" should be implemented based on the business community and civil society structures of the region following the principle of co-creation. However, when information flows between the participants of the digital regional system are not created, such a procedure turns out to be difficult to implement in practice. In addition, the regional management system should have special mechanisms to motivate the business community to implement socially significant functions at the regional level (Stepanova et al., 2019). The emergence of organizational risk factors is possible when choosing a business model of the digital ecosystem of the region that does not correspond to the available resource capabilities of the region and the ability of subjects to implement it. For example, when the technological infrastructure of the region is not ready for the full functioning of the digital ecosystem. In addition, organizational difficulties create problems of interdepartmental coordination and extraction of the synergy of network partnership opportunities, as well as the lack of trust of ecosystem participants in regional institutions (Samorodova et al., 2019). Epidemiological risk factors should not be ignored in the last two years. In particular, the impact of the COVID-19 pandemic on the processes of regional development and digitalization. We are talking about the rapid spread of infection and the unpredictability of the effects of the pandemic when the formed channels of the interaction of subjects were disrupted, the processes of development of the digital regional infrastructure were suspended, and the measures taken by the state adversely affected all subjects of the digital regional ecosystem, bringing economic and social losses (Karpunina et al., 2021; Lisova et al., 2020).

Statistical methods can be used to assess the risk factors for the development of a digital regional system, for example, the variance method. This method is suitable for homogeneous events. With the help of variance, the measure of the spread of a quantity relative to its mathematical expectation is estimated. However, such an assessment is currently difficult due to the lack of regional statistics reflecting the emergence of risk factors of the digital regional ecosystem (Karpunina et al., 2022).

At the final stage, it is necessary to determine the directions for improving the digital regional ecosystem. In our case, it is advisable to neutralize risk factors by adjusting the institutional foundations of the functioning of the digital regional ecosystem; improving the digital literacy of all subjects; debugging communication interactions between all subjects; improving the public administration system in the implementation of joint projects aimed at the development of the digital regional ecosystem. Effective measures are the coordination of interests and actions of all subjects of the digital regional ecosystem; adjustment of the activities of authorities and business structures following the data-oriented approach, as well as the development of digital infrastructure; the use of project management principles in the development of the digital regional ecosystem (Lyshchikova, 2020). It is also important to prepare the regional community for technological changes by forming the foundations of digital culture.

The proposed model for the analysis of the digital regional ecosystem contributes to the rapid identification of risk factors for its development, as well as to take timely measures aimed at levelling them.

5 Conclusions

Firstly, the authors proposed their vision of the structure and content of the "digital regional ecosystem". The expediency of applying a subject-infrastructure approach to the study of digital regional ecosystems is substantiated. Secondly, a model for assessing the state of the digital regional ecosystem is proposed. It includes the following stages: structuring the digital regional ecosystem following the subject-infrastructure approach; selection of indicators to assess the components of the digital regional ecosystem and subsequent calculation of integral indicators; risk factors study; identification of directions for improving the digital regional ecosystem. The content of each stage of the model implementation is disclosed. Thirdly, the proposed model for assessing the state of the digital regional ecosystem has been tested on the example of several regions of Russia and confirmed the authors' assumption about the differences in the development of digital ecosystems of regions.

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Data Availability

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Prospects for the Development of Export-Oriented Agricultural Production in the Stavropol Region

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Abstract The agricultural market is determined, on the one hand, by external factors, on the other, by internal ones. Internal factors include production, sales and consumption. Using competitive advantages, agricultural organizations of the Stavropol Region are increasing the production of basic types of agricultural products. Export-oriented production of agricultural products, at first glance, is not an urgent direction for the development of the economy of the Stavropol region, since the share of exported agricultural products in the total volume of production and sales is small. At the same time, an increase in the share of exported agricultural products in total sales may improve the financial results and efficiency of agricultural production in the region. This article proposes tools for assessing the prospects for the development of export-oriented agricultural production in the Stavropol region for the medium term (until 2025).

Keywords Export-oriented production · Agricultural production · Forecasting methods

JEL Codes A10 · Q18

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_9

1 Introduction

In a market economy, the state should act as the guarantor of the economic activities of companies, form the legal framework for doing business and ensure fair competition. The use of measures and instruments of state influence on export activities should be aimed at strengthening the competitive position of national exporters in the world market, smoothing out imbalances caused by political and economic instability (Litvinova et al., 2017; Tatuev, 2011). The experience of developed countries testifies to the presence of close cooperation between government agencies providing export support with exporting enterprises, trade and financial organizations. Enterprises that use government support are more likely to gain a competitive edge in foreign markets (Galazova et al., 2018).

At the same time, export activities are influenced by various national and international trade and economic factors of the external environment, which require a systematic study. Prospects for further research in this direction are the identification of export promotion instruments that most affect the export orientation of enterprises (Dzhukha et al., 2017; Kiseleva et al., 2017).

Prospects for the development of export-oriented agricultural production in the Stavropol region can be assessed using statistical tools for studying trends and econometric tools for forecasting the volume of exports of products (Kiseleva et al., 2018; Kuzminov et al., 2018).

2 Methodology

For the scientific substantiation of the promising volumes of export of vegetables in open and protected ground in the practice of economic research, methods of prospective extrapolation of time series are successfully applied (Kuzminov et al., 2018; Tatuev, 2010). The proposed methodology for its modelling and forecasting is shown in Fig. 1.

The first stage in the implementation of the proposed methodology involves setting the goal and objectives of the study. In our case, the goal is to assess the predicted values of indicators characterizing the formation of the volume of exports of vegetables in open and protected ground by agricultural organizations of the Stavropol region, based on the construction of quantitative models describing the change in the levels of the time series (Yarkova, 2019; Yarkova & Svetlakov, 2013).

At the next stage, it is necessary to determine the variable considered as the effective indicator. The content of such an indicator should disclose the essence of the process under study, both qualitatively and quantitatively. In our case, we consider it reasonable to use the volume of exports of wheat, sunflower and vegetables by agricultural organizations of the Stavropol region as predicted variables (Ashkhotov et al., 2018).

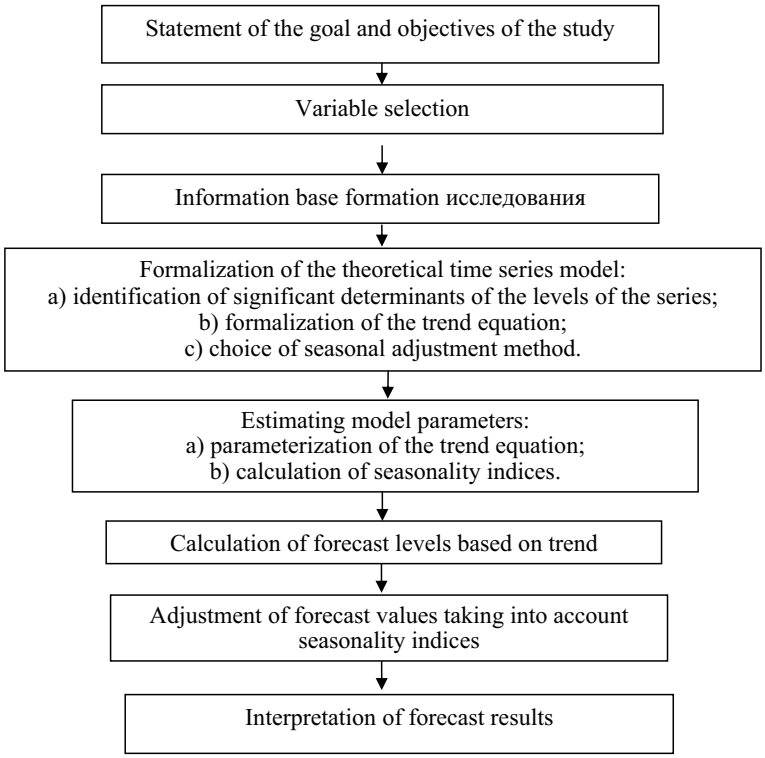

Fig. 1 Methodology for modelling and forecasting the volume of export of crop products by agricultural organizations of the Stavropol Region. *Source* Compiled by the authors

Next, it is necessary to form a statistical base for the study of a sufficient period for predictive estimates. The proposed methodology involves forecasting the indicator for the period up to 2025. Therefore, in our opinion, a study in the context of monthly intervals for the period 2016–2020 seems to be sufficient to obtain effective forecast estimates (Rossinskaya et al., 2019).

As a result of the implementation of this stage, based on customs statistics data, we have formed a statistical base for the study of a sufficient volume (Nagoev et al., 2019).

The formalization of the theoretical model, assumed in the implementation of the next stage of the proposed methodology, provides for the identification of factors that have a significant impact on the size of exports of agricultural products of the Stavropol region.

As you know, the changes in the level of some dynamics are influenced by factors of various types of influence. Of these, the following groups of factors are distinguished that determine the corresponding components of some dynamics:

– factors of an evolutionary nature are factors of long-term impact that determine the general trend in the development of the process;
– cyclical factors that determine fluctuations in the levels of a series as a result of seasonal processes;
– factors of irregular impact, the influence of which cannot be determined by a quantitative model of the time series.

Based on the analysis of the econometric dependence, we built the following trend models: linear, logarithmic, inverse and power. Based on a meaningful analysis of the identification stage of the econometric study, we have chosen linear models for the analytical levelling of the volume of exports of wheat, sunflower and vegetables by agricultural organizations of Stavropol (Bogoviz et al., 2018).

Let us determine the forecast value of wheat exports by agricultural organizations of the Stavropol region for each month of the year for the period up to December 2025, and then adjust the obtained forecast values to the corresponding seasonality indices.

3 Results

The results of forecasting the volume of wheat exports, sunflower exports and agricultural organizations of the Stavropol region are shown in Fig. 2. The use of seasonality indices to assess the dynamics of market conditions allows us to establish that in the short term, a tendency of growth in the volume of wheat exports by agricultural organizations of the Stavropol region for the period up to 2025 has formed. By the end of the forecast period (December 2025), the volume of wheat exports by agricultural organizations in the Stavropol region will reach 16,986 kg, which is 6,234.4 kg or 1.58 times more than in December 2020. Taking into account the seasonal nature of wheat exports by agricultural organizations of the Stavropol region, the highest value will be achieved in August 2025, and the lowest in February 2021.

The use of seasonality indices to assess the dynamics of the market situation allows us to establish that in the short term, there is a trend of growth in the volume of sunflower exports by agricultural organizations of the Stavropol region for the period up to 2025. By the end of the forecast period (December 2025), the volume of sunflower exports by agricultural organizations in the Stavropol region will reach 358.3 kg, which is 151.2 kg or 1.73 times more than in December 2020. Taking into account the seasonal nature of sunflower exports by agricultural organizations of the Stavropol Region, the highest value will be achieved in October 2025, and the lowest—in July 2021.

The use of seasonality indices to assess the dynamics of market conditions allows us to draw the following conclusions. By the end of the forecast period (December 2025), the volume of export of vegetables in open and protected ground by agricultural organizations of the Stavropol region will reach 3,332.0 kg, which is 1,136.9 kg or 1.52 times more than in December 2020. Taking into account the seasonal nature

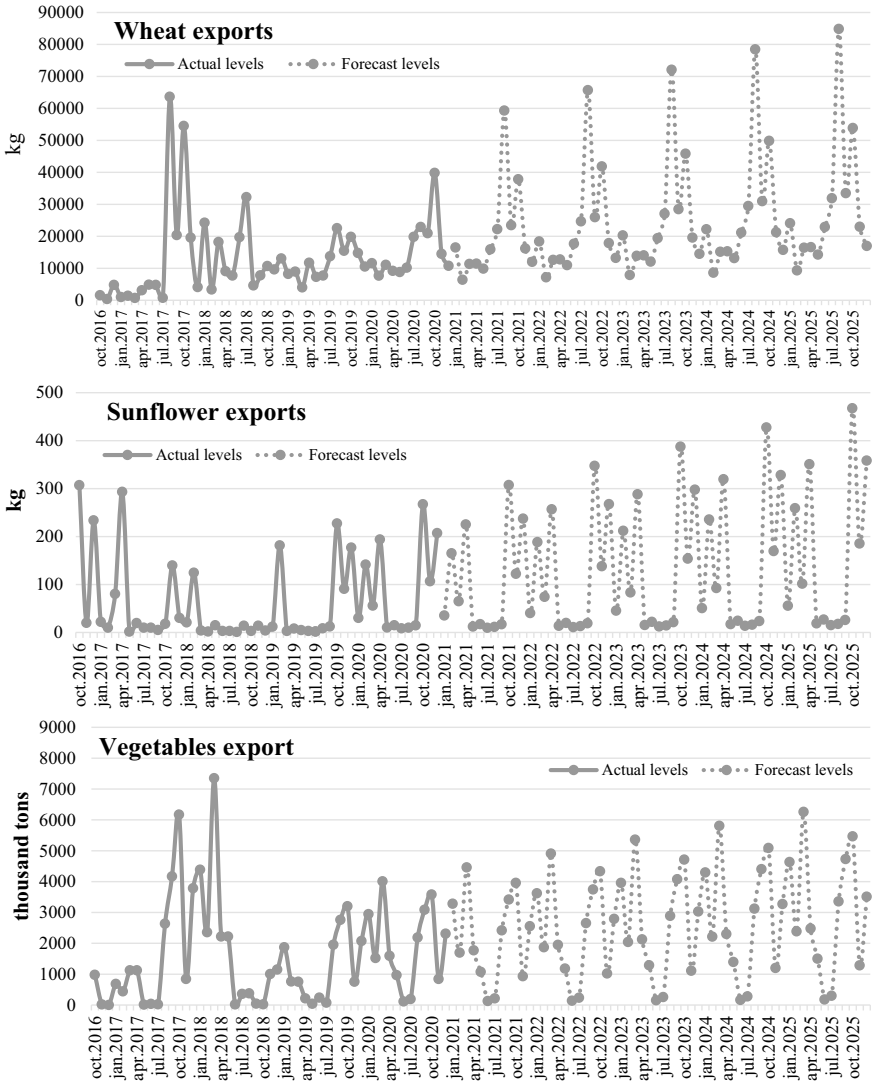

Fig. 2 The results of forecasting the volume of exports by agricultural organizations of the Stavropol Region *Source* Compiled by the authors

of the export of vegetables to open and protected ground by agricultural organizations of the Stavropol region, the highest value will be achieved in March 2025, and the lowest in July 2021.

Table 1 shows the generalized results of forecast estimates of production, sales and export of wheat, sunflower and vegetables by agricultural producers of the Stavropol Region under the inertial scenario.

Table 1 Forecasting volumes of production, sales and export of wheat, sunflower and vegetables under the inertial scenario

	Wheat, thousand tons			Sunflower, thousand tons			Vegetables, thousand tons		
	Production	Selling	Export	Production	Selling	Export	Production	Selling	Export
2017	8,066	7,270.6	708	492.4	452.9	0.639	144.5	113.2	23.1
2018	7,306.8	7,127.6	441	427.3	363.4	0.208	137.4	127.3	33.5
2019	7,740.5	7,185.7	578	438.2	434.4	0.730	144.2	119.7	20.3
2020	7,954.4	7,474.9	719	457.8	446	1.061	150.9	123.9	32.2
2021	8,174.2	7,775.6	781	482.4	453.5	1.225	157.4	127.7	36
2022	8,400	8,088.5	843	508.4	460.5	1.389	163.7	131.4	39.8
2023	8,632.2	8,414	905	535.7	467.2	1.554	169.8	134.8	43.6
2024	8,870.7	8,752.5	967	564.5	473.6	1.718	175.8	138	47.4
2025	9,115.8	9,104.7	1,030	594.9	479.8	1.883	181.7	141.1	51.2

Source Compiled by the authors

So, from 2020 to 2025, the volume of wheat production will increase from 7,954.4 thousand tons to 9,115.8 thousand tons, that is, there will be an increase of 1,161.4 thousand tons or 14.6%. The volume of wheat sales under the inertial scenario from 2020 to 2025 will increase from 7,474.9 thousand tons to 9,104.7 thousand tons, that is, there will be an increase of 1,629.8 thousand tons, or 21, 8%. The volume of wheat exports under the inertial scenario from 2020 to 2025 will increase from 719 tons to 1,030 tons, that is, there will be an increase of 311 tons or 43.3%.

Under the pessimistic scenario, the volume of wheat production from 2020 to 2025 will increase from 4,939.9 thousand tons to 5,461.7 thousand tons, that is, there will be an increase of 521.8 thousand tons or 11%. Under the pessimistic scenario, the volume of wheat sales from 2020 to 2025 will increase from 4,906.5 thousand tons to 5,112.71 thousand tons, that is, there will be an increase of 206.2 thousand tons or 4.2%. Under the pessimistic scenario, the volume of wheat exports from 2020 to 2025 will increase from 719 tons to 1,030 tons, that is, there will be an increase of 311 tons or 43.3%.

The volume of wheat production under the optimistic scenario from 2020 to 2025 will increase from 12,808.4 thousand tons to 16,253.2 thousand tons, that is, there will be an increase of 3,444.8 thousand tons or 26, 9%. The volume of wheat sales under the optimistic scenario from 2020 to 2025 will increase from 11,387.6 thousand tons to 15,177.5 thousand tons, that is, there will be an increase of 3,789.9 thousand tons or 33.3%. Under the optimistic scenario, the volume of wheat exports from 2020 to 2025 will increase from 719 tons to 1,030 tons, that is, there will be an increase of 433 tons or 43.3%.

According to the inertial scenario, the volume of sunflower production from 2020 to 2025 will increase from 457.8 thousand tons to 594.9 thousand tons, that is, there will be an increase of 137.1 thousand tons or 29.9%.

The volume of sunflower sales under the inertial scenario from 2020 to 2025 will increase from 446 thousand tons to 479.8 thousand tons, that is, there will be an increase of 33.8 thousand tons or 7.6%. The volume of sunflower exports under the inertial scenario from 2020 to 2025 will increase from 1.06 tons to 1.88 tons, that is, there will be an increase of 0.82 tons or 1.77 times.

Under the pessimistic scenario, the volume of sunflower production from 2020 to 2025 will increase from 323.4 thousand tons to 390.1 thousand tons, that is, there will be an increase of 66.7 thousand tons or 20.6%. Under the pessimistic scenario, the volume of sunflower sales will increase from 311.1 thousand tons to 329.5 thousand tons from 2020 to 2025, that is, there will be an increase of 18.4 thousand tons or 5.9%. Under the pessimistic scenario, the volume of sunflower exports will increase from 1.06 tons to 1.88 tons from 2020 to 2025, that is, there will be an increase of 0.82 tons or 1.77 times.

Under the optimistic scenario, the volume of sunflower production from 2020 to 2025 will increase from 648.1 thousand tons to 907.2 thousand tons, that is, there will be an increase of 259.1 thousand tons or 40.0%. Under the optimistic scenario, the volume of sunflower sales will increase from 639.4 thousand tons to 698.7 thousand tons from 2020 to 2025, that is, there will be an increase of 59.2 thousand tons or 9.3%. Under the optimistic scenario, the volume of sunflower exports will increase from 1.06 tons to 1.88 tons from 2020 to 2025, that is, there will be an increase of 0.82 tons or 1.77 times.

The production volumes of vegetables in open and protected soil in the Stavropol region under the inertial scenario from 2020 to 2025 will increase from 150.9 thousand tons to 181.724 thousand tons, that is, there will be an increase of 30.8 thousand tons or 20.4%. The sales volumes of vegetables in open and protected soil in the Stavropol region under the inertial scenario from 2020 to 2025 will increase from 123.9 thousand tons to 141.1 thousand tons, that is, there will be an increase of 17.3 thousand tons or 13.9%. The export volumes of vegetables in open and protected soil in the Stavropol region under the inertial scenario from 2020 to 2025 will significantly increase from 32.3 tons to 51.2 tons, that is, there will be an increase of 19.1 tons or 1.6 times.

4 Discussion

Under the pessimistic scenario, the production volumes of vegetables in the open and protected ground in the Stavropol region will increase from 99.3 to 113.0 thousand tons from 2020 to 2025, that is, there will be an increase of 13.6 thousand tons, or 13.7%. Under the pessimistic scenario from 2020 to 2025, the volume of sales of vegetables in the open and protected ground in the Stavropol region will increase from 95.7 to 110.8 thousand tons, that is, there will be an increase of 15.2 thousand tons or 15, 9%. Under the pessimistic scenario from 2020 to 2025, the export volumes of vegetables in the open and protected ground in the Stavropol region will increase from 32.2 to 51.2 tons, that is, there will be an increase of 19 tons or 1.6 times.

The optimistic scenario makes it possible to predict an increase in the production of vegetables in the open and protected ground in the Stavropol region from 2020 to 2025 from 237.9 to 292.3 thousand tons, that is, there will be a noticeable increase, which will be 54.4 thousand tons, which in relative terms will exceed the level of 2020 by 22.8%. The optimistic scenario makes it possible to predict an increase in the sales of vegetables in the open and protected ground in the Stavropol region from 2020 to 2025 from 154.5 to 179.7 thousand tons, that is, there will be an increase that will amount to 25.2 thousand tons, which in relative terms will exceed the level of 2020 by 16.3%. The optimistic scenario makes it possible to predict an increase in the export volumes of vegetables in the open and protected ground in the Stavropol region from 2020 to 2025 from 32.2 to 51.2 tons, that is, there will be an increase of 19 tons, which in relative terms will exceed the level of 2020 1.6 times.

5 Conclusion

Practical testing of the proposed methodology makes it possible to build models, carry out medium- and long-term forecasting and analyze the dynamics of export of products by agricultural producers in the Stavropol Region.

International trade is a priority area for the active development of the regions. It creates a solid base for attracting additional funds to the economy of the subject, as well as large foreign investments. It is export-oriented enterprises that are the locomotive of the development of industry and the economy as a whole. They accumulate valuable material and financial resources, attract highly qualified personnel, are the main users of inventions and innovations, provoke structural changes in the sectors of the economy.

In our opinion, measures to promote exports include the creation of favourable geopolitical and trade and economic conditions for exporting enterprises, targeted programs to stimulate exports, liberalization of administrative regulation, institutional, financial and information assistance to exports.

We believe that the following measures can be used to stimulate exports: the creation of good trade, economic, geopolitical conditions for exporters, targeted export incentive programs, assistance to exports in the financial, informational and institutional spheres.

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The Value of Cooperation and Tendencies of Its Development in the Agricultural Business of Geostrategic Border Territories

Olga A. Moiseeva

Abstract The approved "Spatial development strategy of the Russian Federation until 2025" aims to develop agriculture of geostrategic border areas through the cooperation of producers of agricultural products, providing access to markets, including outside the country, and increasing the share of sales of products with high added value. During the creation and functioning of cooperatives, producers of geostrategic border territories face several problems, including the low level of state support from the federal and regional authorities, the lack of understanding of the goals and objectives of cooperation, the low interest of cooperative members in its patronage, and the presence of subsidiary responsibility of cooperative members for its obligations. The legislation provides for the possibility of supporting cooperatives established and operating only in traditional forms; other cooperative practices are not subject to support. Developed countries give cooperatives the leading role in the processing, promoting, and selling of agricultural products. The main trends in the development of cooperatives are associated with the enlargement of cooperative business, the development of vertical integration, innovation, and digitalization, and the provision of a wide range of state support mechanisms. The main participants-investors of such cooperatives are representatives of small forms of farming. The organizational structure of most foreign cooperatives differs from the traditional one (it does not always use the principle "one participant-one vote," liability for the obligations of the cooperative, etc.), which ensures their high competitiveness. The analysis of the best foreign practices links the development of cooperatives in the agricultural business of geostrategic border areas with an increased role of state support, increasing the scale of activities, access to markets for organic products, and the export of agricultural products with high added value.

Keywords Cooperation · Agricultural consumer cooperatives · Border geostrategic territories · State support · Subsidiary responsibility · Small business · Export of agricultural products

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_10

JEL Codes Q13 · O18

1 Introduction

"Spatial development strategy of the Russian Federation until 2025" (Strategy) aims to ensure the national security of the Russian Federation through socio-economic development of geostrategic territories by stimulating cooperation of border constituent entities of the Russian Federation with neighboring countries. This cooperation should be aimed at reducing the unequal interaction in terms of exports from border regions of the Russian Federation of raw materials and low value-added products and imports of finished products (Government of the Russian Federation, 2019).

During the implementation of the Strategy, it is expected to increase the competitiveness of the economy of rural areas, promote the development of small businesses and consumer cooperation, and ensure the availability of markets for agricultural products and deep processing for commodity producers to increase the proportion of products with high added value.

One of the main areas of implementation of the stated goals of the Strategy is designated cooperation. In translation from the Latin, *cooperation*—joint work, actions aimed at solving specific problems of specific individuals. In different countries and at different times, cooperatives have emerged as a tool to offset the costs of a market economy.

For the agriculture of geostrategic border territories, the priority areas of activity based on cooperation are processing, pre-sale preparation, sale of agricultural products, and purchasing necessary material and technical resources. A significant contribution to the production of agricultural products of geostrategic border territories is made by small forms of farming (SFF); their share in the structure of production averaged 40–45% for 2016–2020. The development of cooperation will also increase their sustainability and efficiency and expand opportunities for production and sale of products, particularly for export. Given consumer concerns about food quality, cooperatives can and should seek to take a leading position in the market for organic products and products with improved characteristics.

2 Methodology

The research aims to study the activities of cooperatives functioning in the geostrategic border areas, identify problems in their activities, and search and justify the prospects for their development, considering the experience of support and successes achieved by agricultural cooperatives in some foreign countries. Analytical, monographic, and statistical research methods were used during the research. Additionally, the research used materials obtained from the official sources (websites)

of the Ministry of Agriculture of Russia, the federal project "Export of agricultural products," Federal State Statistics Service of the Russian Federation, and the works of Russian and foreign scientists.

3 Results

In the geostrategic border territories, there were registered 1569 units of agricultural consumer cooperatives (ACC) (27% of the total number of cooperatives registered in Russia as of January 1, 2021), including processing cooperatives—26%, trading cooperatives—19.1%, and serving cooperatives—17.5%. The number of registered ACCs in geostrategic border territories significantly varies from 10 units in the Pskov Region (the smallest number) to 211 units in the Belgorod Region. The leaders in the number of ACCS, in addition to the Belgorod Region, are the Krasnodar Territory (169), the Tyumen Region (155), the Volgograd Region (133), and the Saratov Region (102). Less than 30 cooperatives are registered in the Kursk (21), Bryansk (22), and Leningrad regions (29) (Table 1). As of the beginning of 2020, the regions leading in the number of registered ACCS are the Lipetsk Region (740), the Republic of Bashkortostan (310), the Penza Region (292), the Republic of Tatarstan (271), and the Republic of Sakha (Yakutia) (304).

In general, the number of processing and service cooperatives in the country has grown, while the number of sales, supply, and credit cooperatives has decreased. Of the total number of cooperatives registered in the country as of January 1, 2020 (5742 units), about 3750 are in operation. A similar trend with a change in the number of cooperatives is also observed in the geostrategic border territories. According to the primary data received from organizations, in 2015–2020, the share fund of supply and trade cooperatives in most regions included in the geostrategic border territories has increased (on average 1.2 times). Simultaneously, the number of members of such cooperatives has decreased (on average by 30%). There is almost an eight-fold increase in the value of shipped goods of own production, indicating the processes of concentration and the growth of the scale of cooperative activities (Federal State Statistics Service of the Russian Federation, Rosstat, n.d.).

The "National report on the progress and results of the Federal program 'Development of agriculture and regulation of markets of agricultural products, raw materials and food'" (as part of the implementation of the federal project "Creation of support system for farmers and development of rural cooperation") notes that 247 ACCs received state support from the federal budget in 2019 and 277 units in 2020 (23.8% of the plan), which is only 4.8% of the total number of registered ACCs. That is, 95% of cooperatives were not covered by state support. The share of ACCs receiving subsidies by type of activity in 2020 was represented by processing cooperatives (43.7%), trade cooperatives (24.6%), and servicing cooperatives (2.6%). The average amount of funds allocated to one ACC was 2411.3 thousand rubles in 2019, and 1631.96 thousand rubles in 2020. In aggregate, the amount of federal project

Table 1 The number of agricultural consumer cooperatives in the geostrategic border territories as of January 1, 2021

		Consumer cooperatives						Total
		Processing	Serving	Trade	Supply	Credit	Other	
	Russia	**1593**	**870**	**888**	**303**	**764**	**1398**	**5816**
1	Altay Territory	11	11	3	1	7	23	**56**
2	Astrakhan Region	8	8	8	–	6	5	**35**
3	Belgorod Region	35	39	32	12	3	90	**211**
4	Bryansk Region	8	6	2	1	–	5	**22**
5	Volgograd Region	23	14	32	7	40	17	**133**
6	Voronezh Region	23	33	8	11	3	9	**87**
7	Krasnodar Territory	51	22	40	1	20	35	**169**
8	Kurgan Region	15	6	3	3	2	2	**31**
9	Kursk Region	7	8	1	–	–	5	**21**
10	Leningrad Region	8	4	3	1	4	9	**29**
11	Novosibirsk Region	11	6	2	–	5	11	**35**
12	Omsk Region	30	5	9	–	3	3	**50**
13	Orenburg Region	11	6	22	12	3	19	**73**
14	Pskov Region	2	2	–	1	1	4	**10**
15	Republic of Altay	42	3	4	3	2	28	**82**
16	Republic of Tuva	23	–	5	2	–	2	**32**
17	Rostov Region	29	14	21	5	23	3	**95**
18	Samara Region	18	5	7	5	6	20	**61**
19	Saratov Region	16	33	33	3	9	8	**102**
20	Smolensk Region	9	9	14	1	2	5	**40**
21	Tyumen Region	21	37	38	6	23	30	**155**
22	Chelyabinsk Region	7	4	13	2	5	9	**40**
	Total number of ACCs in the geostrategic border areas	408	275	300	77	167	342	1569
	Proportion of the total number in the Russian Federation	25.6	31.6	33.7	25.4	21.9	24.5	26.9

Source Compiled by the authors based on (Federal State Statistics Service of the Russian Federation, Rosstat, n.d.).

financing equaled 3.831 billion rubles (from the federal budget) in 2020, including the following:

- Agrostartap grants—3.2 billion rubles (84.4%);
- Subsidies to ACCs—0.4 billion rubles (10.8%);
- Reimbursement of expenses of competence centers—0.2 billion rubles (4.8%).

In 2021, it was planned to spend 5148 billion rubles to implement the specified actions. It was also planned to involve not less than 11,623 people in the development of agribusiness and support at least 1200 peasant (farm) enterprises (P(F)E) and 394 ACCs (Ministry of Agriculture of the Russian Federation, 2021a).

The top 10 subjects of the Russian Federation stimulating the development of ACCs through subsidies, include the following regions:

- Irkutsk Region (the share allocated for subsidies to ACCs—42%);
- Saratov Region (40%);
- Volgograd Region (33%);
- Ivanovo Region (26%);
- Orel Region (24.7%);
- Chelyabinsk Region (24.6%);
- Lipetsk Region (24%);
- Udmurtian Republic (21%);
- Tyumen Region (19.9%);
- Kaluga Region (19.5).

Thus, the current financial measures to support SFF and ACCs at the federal level aim to reimburse part of the costs, provide grants to the P(F)Es on a competitive basis, and co-finance the costs of competence centers in the field of agricultural cooperation (Ministry of Agriculture of the Russian Federation, 2021a). The number of people involved in small and medium-sized businesses is growing (1588 new members from among small and medium-sized businesses and citizens engaged in private subsidiary plots joined cooperatives, though the planned indicator for 2020 was 9616 units). Nevertheless, the analysis shows that the increase in the number of cooperatives and their members in most regions of geostrategic border territories is associated with the possibility of receiving state support in conditions of significant limitation of own financial resources. Therefore, such cooperatives are created rather quickly while only formally uniting nearby farms, which differ significantly in the level of technological equipment and the volume of production and financial activities. The intra-economic mechanism of such organizations does not comply with the principles of creation and functioning of effective cooperatives; its activities are not planned for the medium and long term. It should also be noted that only registered cooperatives operating according to the traditional model can benefit from state support. Cooperatives created in this way are not viable; only two-thirds of the total number of registered cooperatives are engaged in any activity. The stated amount of federal funding does not help support rural cooperation and increase its competitiveness; it does not cover most of the ACCs. Other forms of small business support do not require small businesses to join an agricultural cooperative.

In some subjects of the Russian Federation (Lipetsk Region, Republic of Sakha, and Tyumen Region), the situation with the development of cooperation significantly differs, which is explained by the presence of existing regional programs, coordinated actions of regional authorities and representatives of cooperatives, three-tier system of cooperation, construction of agricultural cooperative markets, the sale of products through electronic services, and popularization of cooperative ideas. According to paragraph 1 of article 7 of FZ-193, "the state stimulates the creation and supports the activities of cooperatives by allocating them funds from the federal budget and the budgets of the subjects of the Russian Federation for the acquisition and construction of processing and service enterprises, the creation of credit and insurance cooperatives based on the developed plans and forecasts of development of territories and target programs, provides scientific, personnel, and information support" (Russian Federation, 1995). Thus, the declared regime for cooperatives is not fully implemented at the federal and regional levels.

Undeniable advantages of cooperation and the viability of various forms of cooperatives have been repeatedly discussed in the studies of Russian and foreign scientists and specialists (R. Owen, F. Raiffeisen, A. V. Emelyanov, A. V. Chayanov, A. A. Nikonov, et al.) (Chayanov, 1991; Emelyanov, 2020) and were successfully implemented in the practical activities of commodity producers of the industry of developed economies. This allows us to confidently assert that true cooperatives can and should ensure an increase in the efficiency of production and financial activities, in particular SFF (Moiseeva, 2021b).

According to the current Russian legislation, the specifics of the cooperative as an organizational and legal form allows its participants to obtain several advantages, including the following:

- Ensure the growth of income of cooperative members;
- Provide the opportunity to enter domestic and foreign markets;
- Build customer loyalty to cooperative products through recognition of the trademark and loyalty to it.

The stated advantages of cooperation are realized if the members of the cooperative are homogeneous (homogeneity is achieved through similar production and financial results or volumes of consumption of cooperative services), have a clear idea of the goals and features of the cooperative form, and are willing to act as patrons of their cooperative (Moiseeva, 2021a). Simultaneously, according to the current law, the cooperative members must bear full subsidiary liability for their obligations. Foreign experience shows the possible limitation of the amount of subsidiary liability (according to the statute of the cooperative in Germany, there is a cooperative without additional liability, with limited additional liability, and unlimited (full) liability of members) (Paptsov, 2021).

Currently, the share of Russian supplies in global agricultural exports is 1.6%. In 2019, in the total volume of Russian exports, the share of domestic food exports reached 5.9% (the global average—8%). In other words, the scale of Russian agri-food exports is rather limited. The Russian Federation ranks 20th in the world in terms of agri-food export volumes. The USA, Holland, Germany, Brazil, and China

occupy the leading positions in the world. In the above countries, except Brazil, a significant portion of exports comes from high value-added products (Altukhov et al., 2021).

A federal project "Export of agricultural products" with a budget of 406.8 billion rubles was launched to ensure sustainable growth of non-resource and non-energy exports of the country and increase the efficiency and competitiveness of Russian food products. The project's passport includes about twelve names of results and their characteristics. As a result of the project's implementation, the volume of exports of agricultural products is planned to increase from $25 to $45 billion by 2030 due to the creation of a new commodity mass, including those with high added value. The analysis of state support measures for exports and conditions for its receipt suggests that state support for exports is available not only to agricultural producers but also to product processors, trading companies, and SPV companies (a company created for a special export project) (Ministry of Agriculture of the Russian Federation, 2021b). Thus, cooperatives in the Russian and foreign markets need to compete with large companies whose sales volumes and revenues exceed cooperative revenues many times over and who have a monopolistic market position, recognizable trademarks, established concepts of business models, and wide geography of supply.

The highly competitive global market and non-tariff restrictions on imports significantly reduce the opportunities for small businesses to develop exports independently. The experience of foreign countries shows that it is necessary to improve the effectiveness of the organizational mechanism and trade and political measures to support cooperatives. State support for agricultural cooperation in Germany, Denmark, Finland, and Canada contributed to the monopolization of cooperatives in the processing and sale of most or certain types of agricultural products. The largest processing and marketing cooperatives have gained dominant influence, acquiring the features of large corporations. They are not subject to antimonopoly legislation because they ensure the development of small businesses in the industry. Therefore, conditions of preferential economic activity (in the area of credit, taxation, subsidies, and monopoly right to import some food products) are created for cooperatives of farmers, despite the scale of their activity. The internal structure of most cooperatives corresponds to some kind of joint-stock company; the cooperative legislation provides for a wide range of organizational structures, which significantly increases their competitiveness. In addition to achieving high financial performance and international activities, in many countries, cooperatives carry out strategic tasks aimed at reducing greenhouse gas emissions, improving the livelihood of their employees (e.g., BayWa cooperative, Germany), ensuring food safety, and taking responsibility for the preservation of the natural human environment (e.g., FrieslandCampina cooperative, Netherlands). As for state support, the main trends are that support is provided mainly for small cooperatives, which are not highly efficient and perform the necessary functions on a regional scale (rural development and employment). Large cooperatives are supported by the scale of their activities only in extreme cases (e.g., climatic, epidemiological factors, etc.) (Golovina et al., 2021).

4 Conclusion

The development of cooperation in the agricultural business of geostrategic border areas is primarily related to the following:

- further theoretical research in the field of cooperation, analysis of contemporary forms of cooperative organizations, improvement of cooperative legislation, and increased funding to ensure the most favorable regime for cooperatives by federal and regional authorities;
- Processing, pre-sale preparation, and sale of products on the domestic food market; ensuring recognition of Russian agricultural products in domestic and foreign markets. Products sold under a recognizable trademark are highly appreciated by consumers. Thus, cooperative products marked with a certain trademark will be a success in the Russian and foreign markets;
- Entering the markets of organic products and products with improved characteristics, exporting products (development of business models, tools to support export-oriented agricultural cooperatives, and increasing the scale of their activities).

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Current Global and Russian Trends in the Development of Investment and Innovation in the Agro-Industrial Complex

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Abstract The current crisis of the world economy is characterized by the redistribution of cash flows, which is inter-sectoral and territorial in nature. The agricultural economy was particularly affected by the pandemic crisis, and its recovery must be based on a fundamentally new innovative framework that ensures its competitiveness in domestic and foreign markets. Scientific studies give considerable attention to the problems of regulating investment flows in the agricultural economy. However, some problems of innovative transformation of the agro-industrial complex remain understudied, including the problems related to the formation of trends of innovation in the agro-industrial complex, the identification of growth points of new innovative trends, the rationale for improving the state regulation of innovation activity in current conditions, and others. These problems justified the choice of the research topic, its goal, and objectives. The authors of the research aim to identify and develop global and Russian trends in developing investment and innovation in the agricultural sector. In accordance with the goal, the research solves several problems concerning new trends in the development of innovation processes in the global agricultural economy and the agricultural sector of Russia. The primary research results are presented, which are of particular scientific value. The authors substantiate the directions and vectors of investment flows into agricultural production in the global agricultural market. The updated architectonics of the investment attractiveness of the agricultural economy is presented. Trends in the development of the global agro-industrial complex are substantiated. Additionally, the authors identify factors limiting the growth of investment and innovation in agriculture in Russia. Moreover, they form

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_11

vectors of investment of large agricultural companies in the agricultural economy of Russia. The directions for improving the mechanism of state regulation of innovation and investment processes in the agricultural sector of the economy are proposed.

Keywords Innovation · Investments · Trends and development trends · Agricultural economy · Government regulation

JEL Codes E00 · E20 · E22

1 Introduction

Investment and innovative functioning of the agricultural sector of the economy have special problems determined by the features of the industry. The specifics of innovation and investment activity and the role of the government in regulating these processes in the agricultural sector are studied in the works of Ushachev et al. (Altukhov & Ushachev, 2008; Ushachev & Borkhunov, 2009; Gurnovich et al., 2021; Piterskaya et al., 2019; Sklyarova et al., 2019). These scholars focus on the main characteristics, development trends, and methods and tools of regulation of investment and innovation processes in agriculture, as well as several other aspects. However, the current systemic global pandemic crisis, accompanied by a sharp decline in investment flows into agricultural business (especially small and medium-sized), has revealed new problems associated with ensuring sustainable and competitive agricultural production in Russian and foreign agricultural markets. The formation of such production should be based solely on innovation, consistent with contemporary global trends in science and technology. In this regard, the research topic, its goals, objectives, and results are of particular relevance. The paper focuses on the current trends and problems of innovation development in the global and Russian agricultural production, identifies points of growth of innovation development of the industry, and suggests the directions of government regulation of innovation processes in today's conditions in Russia.

2 Methodology

The research design is determined by the purpose and objectives of the scientific work. The authors formed the purpose of the research and the resulting tasks necessary to implement it. The research aims to develop global and Russian trends in innovation processes in the agro-industrial complex (AIC) in the formation of the current scientific and technological paradigm. The research objectives are as follows:

- To analyze and select new vectors of investment development of the global agro-industrial complex;

- To define the current architectonics of investment attractiveness of the global agricultural economy;
- To highlight the factors hindering the development of investment and innovation processes in the agricultural sector of Russia;
- To form a growth point for investment by large companies in the Russian agricultural market;
- To develop ways to improve government regulation of investment and innovation processes in agriculture in Russia.

The research methods correspond to the tasks solved during scientific work. The research was conducted using monographic, analytical, economic-statistical, and other analysis methods. The information base determining the reliability of the research is represented by data from the Federal State Statistics Service of the Russian Federation (Rosstat).

3 Results

Innovation and investment activities of the agricultural industry are undergoing significant changes. This fact is evidenced first and foremost by a significant increase in investment in new technology projects and start-ups. The total investment for 2014–2019 rose to $20 billion, with a 300% increase. It should be noted that the investment flow in agricultural production was concentrated mainly in two vectors:

- Industrial technologies "from the field to the counter" (upstream);
- Consumer technologies "from the counter to the table" (downstream).

The most significant components of consumer technology are "from the field to the table" (Orlova et al., 2020; Kharas, 2017).

The development of consumer technology "from the field to the table" (downstream) of the innovation market of the AIC is justified by urbanization, digitalization, and a shift in value vectors.

This segment shows the most dynamic development in value terms; the growth rate of this segment reaches 34%, and its share in the structure of investment reaches 60%.

In general, there is a predominance of investment in projects at higher stages of the reproduction process, where, as a rule, the level of margin is higher, and risks are lower.

In general, the new architectonics of investment attractiveness of the global agricultural economy is formed along the following lines (Orlova et al., 2020):

1. Innovative agro-biotechnology (more than 58% of interested investors);
2. Innovative technologies for processing, transportation, and storage (more than 40% of interested investors).
3. Innovative food production (56% of interested investors).

Thus, the main vectors in the innovative development of the sectors of the global agro-industrial complex are as follows:

a. Innovative technologies and means of production Agriculture 4.0, actively forming a segment with volumes of $230 billion, or 29% of the total growth in Agriculture 4.0;
b. Development of advanced marketing technologies (online food delivery platforms), which amount to about $80 billion, or 10% of the growth of Agriculture 4.0;
c. Food waste recycling industry is also a dynamic industry that is supposed to generate $13 billion in volume growth;
d. Decrease in the share of final products in agricultural production from 77 to 71%.

The main elements in these areas will be as follows:

1. Production of healthy and organic food can provide up to $419 billion. In addition to healthy food and organic products, this line also includes dietary products and products without ingredients harmful for certain categories of customers (e.g., lactose, gluten, etc.);
2. Production of biofuels can give an increase of up to 68 billion rubles (Government of the Russian Federation, 2012);
3. Production according to the technological solutions of Agriculture 4.0: production of agricultural robots can give an increase in volumes of up to $80 billion; new innovative systems of closed farming, which can give an increase in volumes of $27 billion; and new innovative systems of closed farming, which can give an increase of $27 billion;
4. Production of food processing equipment for healthy food and the introduction of new technologies of preservation and non-thermal methods, which will add about $62 billion by 2025;
5. Development of agricultural biotechnology (the development and production of biological preparations for crop production) and promotion of innovative technologies in the field of genetics and breeding;
6. Innovative technologies that form a safe environment for the supply chain.

Thus, the development of the global AIC in the ten-year perspective will be characterized by the trends presented in Table 1.

Given the innovation trends, the consensus forecast 56 is that the global Agriculture 4.0 market will see a 58% increase to $2.3 trillion by 2025. The final innovative products of the AIC will reach $1.6 trillion by 2025, accounting for 62% of the total growth in Agriculture 4.0 (Orlova et al., 2020). The growth structure of the world's Agriculture 4.0 is shown in Table 2.

As an object of global and innovation investments, Russia is not quite attractive due to the internal economic situation and the underdeveloped technological base in agriculture.

Agricultural enterprises occupy a relatively low share of the international investment market. Financial injections into the shares of Russian agricultural companies

Table 1 Trends in the development of the global AIC

Trends	Trend content
Use of the new technological mode	The nano-, bio-, information-, and cognitive technology-based biotechnologies, transforming factors to ensure the competitiveness of industries, increasing productivity and safety, and reducing agroclimatic and biological risks
Transformation of demand for traditional foodstuffs to new products corresponding to contemporary values and orientations	Increased demand for ready-to-eat foods prepared with pre-determined preferences, tastes, food experiences, and consumers
Changes in value chains	Eliminating intermediaries, ensuring close interaction between consumer and producer, and forming the bulk of the added value in innovative and knowledge-intensive sectors (i.e., genetics, breeding, IT sector, etc.)
Emphasis on the safety, environmental friendliness, and sustainability of agricultural production	Strengthening the role of standardization and certification system, increasing requirements for environmental and safety and ethical compliance
Shaping the knowledge economy and science	The introduction of digitalization in the real economy will transform the employment structure. By reducing the level of low-skilled labor, the need to organize a new model of education focused on rapid adaptation to new conditions will increase

Source Compiled by the authors based on (Orlova et al., 2020; Rosstat, 2021)

are also very restrained because of their increased riskiness. Simultaneously, over the past decade, the agricultural sector of the economy has carried out significant innovative transformations and fully provided the Russian population with food products of its own production (meat, legumes, sugar, and others). The study revealed several factors hindering the growth of investment in agriculture:

- The current trend of decreasing purchasing power of the population has a negative impact on the demand and pricing of agricultural products. Additionally, there is still a high dependence of agricultural production on imported means of production, which negatively impacts the cost of production of Russian producers;
- Differences in sanitary standards of Russian agricultural products are an obstacle to its promotion in foreign markets. Underdeveloped infrastructure and logistics also do not contribute to the competitiveness of Russian agricultural products.

4 Discussion

During the research, based on the study of existing investment trends (Rosstat, 2021; Ministry of Agriculture of the Russian Federation & HSE University, 2017), the

Table 2 Growth structure of Agriculture 4.0 in the world (2025)

Segment	2018	2025	Growth
AIC products	1078	1588	510
Food	905	1336	+430.4
Including healthy and therapeutic nutrition	894.4	1313.7	+419.2
Including organics	140.0	380.0	+240.0
Including other types	10.8	22.0	+11.2
Non-food (biorefining)	173	252	+78.9
Including biofuels	166.0	233.6	+67.6
Including other types	7.2	18.5	+11.3
Including agricultural biotechnology	35.4	63.7	+28.3
Including robotics	7.5	87.9	+80.4
Including precision farming	4.3	13.4	+9.1
Including closed farming	26.0	53.1	+27.1
Including food processing equipment	135.0	196.6	+61.6
Including security and traceability technologies	34.1	53.9	+19.8
Including other types	1.5	4.5	+3.0
Total	1439	2272	+832.4

Source Compiled by the authors (Orlova et al., 2020)

authors formed the directions of investment by large companies in the agricultural sector of the Russian economy. These directions are as follows:

1. *Pork production.* The vectors of market development are price fluctuations, the concentration of production through the absorption of small businesses, and the development of large pork producers with a high level of added value. The trends in pork production that have a negative impact on investors include the low capacity of the market for exports of potential under existing export restrictions and the high cost of building complexes in the current environment (Rosstat, 2021).
2. *Poultry production.* The poultry market is marked with high risks of overproduction, falling poultry meat prices, and falling poultry meat imports. For investors, such market trends fill the investment market with several characteristics, including the possibility of developing poultry exports to the Middle East and Asia with the appreciation of the ruble. Moreover, poultry is the preferred source of protein (especially with a significant decrease in the purchasing power of the population), which affects the growth of the Russian poultry meat production and consumption market.
3. *Milk and dairy products.* The main features of milk market development are a steadily high level of milk consumption in Russia, seasonal fluctuations in milk production volumes and, accordingly, prices for dairy products, significant imports of milk and dry concentrate, significant import substitution with the

operational efficiency of production, high capital intensity of the industry, and long payback periods of investment. For investors, the market for milk and dairy products is characterized by the presence of growth in long-term demand for dairy products and significant demand for long-term investment.

4. *Sugar*. The main characteristics of sugar market development are stable demand on the market of Russia and European countries, fluctuations of sugar prices on the international market, growth of cultivated areas, reduction of sugar prices, and limited export infrastructure. Investment characteristics of the industry include a high level of capital consolidation in the hands of large sugar producers, excessive processing capacity, and limited growth of cultivated areas under current conditions (Rosstat, 2021; Ministry of Agriculture of the Russian Federation & HSE University, 2017).
5. *Vegetable oils*. The key market trends include high price volatility, high market saturation in Russia, almost no export opportunities due to limited world market volumes, dynamic development of import supplies, and active application of palm oil in the food industry. For investors, this industry is characterized by the following features: a high level of capital concentration through mergers and acquisitions and a high level of overcapacity and saturation of the vegetable oil market.
6. *Agrotechnologies*. This market is marked with significant demand from large agricultural holdings in science-intensive areas (i.e., genetics, robotics, data collection and analysis, etc.). For investors, the peculiarities of the agrotechnology market include a limited number of independent scientific developers and a high capacity of the agrotechnology market for developers of new innovative technologies (Orlova et al., 2020; Rosstat, 2021).

In general, the characteristics of the crop industry include the following features:

- Price volatility on the world market (low enough);
- The overstocking of world markets with crop products;
- The attractiveness of grain trading;
- High level of natural, climatic, and other risks.

Investment features of the crop industry are as follows:

- The quality of land and developed infrastructure are of particular importance in investing;
- There are large, medium, and small enterprises in the industry.

Investment processes in the agricultural sector of the economy require active government support (Kharas, 2017; Piterskaya et al., 2019).

State regulation of investment and innovation processes in agriculture is carried out to solve the following tasks:

1. To form and develop a favorable business environment;
2. To form a business-friendly taxation system;
3. To develop the training system for agricultural producers;
4. To provide working capital to agricultural producers promptly;

5. To ensure timely, innovative, and accessible technological and technical support;
6. To contribute to the formation of sustainable product sales;
7. To ensure the availability of credits, etc.

Improvement of government regulation of investment and innovation processes in agriculture should be carried out in the following directions:

1. Modernization of the institutional environment. Significant structural changes in the agrifood market are accompanied by the development of new markets and active implementation of fundamentally new technologies, which entails the complexity of the institutional environment and architecture of standards. In accordance with this, it is necessary to form a flexible system with new levers of legal regulation, capable of quickly adapting to changing external conditions and using new technologies. It is especially important to ensure the harmonization of Russian and international standards and the implementation of international cooperation in the field of certification and licensing.
2. Transformation of the view of the AIC as an archaic sector of traditional products and technologies, limiting the dominance of the isolationist paradigm in the area of scientific and technological development. The processes of solving the problems of development and strengthening national food security should be transformed into an active transition to innovative development, which contributes to building an effective system of generation of new original ideas and support their transformation into particular solutions, products, and technologies. For this purpose, it is necessary to create and develop new scientific schools, ensure active attraction of international competencies to them, form an environment to support start-ups and venture investments and innovations, and form a set of incentives for localization of advanced industries.
3. Development of the system of transfer support. The current infrastructure of financial support in the agro-industrial complex formally meets the goals and objectives of all stages of innovative projects. Simultaneously, in practice, the existing measures are based only on some forms of support and do not consider the specifics of innovative investments. Additionally, there is almost no support for venture capital investment in AIC technologies, which hinders the development of breakthrough innovative projects forming a new innovative environment.
4. For the organization of innovative processes, their activation, and monitoring, it is necessary to develop a strategic plan of innovative development at the regional level, which would contain the justification of objectives and mechanisms of resource provision of investments, defining the stages of the innovation project, efficiency, payback, and risks of implementing innovative projects.
5. The organization of investment and innovation processes is inextricably linked to the need to ensure the financial sustainability and effective conduct of agricultural business because the profit of organizations is the primary source of investment. In this connection, government regulation of investment and innovation activity of agricultural production should also be aimed at providing

conditions and formation of measures contributing to the growth of production efficiency and economic activity of agricultural producers.

6. The next direction to enhance innovation and investment activity in agriculture is the concentration of fixed capital, scientific research, and the creation of appropriate infrastructure, combining research, information, and communication resources and developing innovation.
7. To improve innovation and investment activities in agriculture, it is necessary to create a unified all-Russian agricultural network, which will become an information platform for interaction between agricultural producers and developers of innovations. It is also necessary to create a regional cluster to develop innovation and investment in the agricultural sector, allowing to combine economic, information, and social resources for innovative development of enterprises (Piterskaya et al., 2019; Sklyarova et al., 2019).

5 Conclusion

The conducted research allowed us to form several conclusions and recommendations. In general, the research results indicate that the tasks formulated in accordance with the purpose of scientific work are solved in full.

In today's conditions, the global agricultural sector needs an active innovative transformation. Thus, innovations must be applied in the following areas:

- Development of agricultural biotechnology (production of biological preparations for crop production and promotion of innovative technologies in the field of genetics, breeding, and biofuel production);
- Technologies for processing, transportation, and storage of agricultural products (technical re-equipment of food production facilities of healthy food, the introduction of new technologies of preservation and non-thermal methods);
- Development of the production of innovative food (healthy and organic food, dietary products, and products without ingredients harmful for certain categories of people);
- Shaping production in accordance with the technological solutions of Agriculture 4.0 (production of agricultural robots, innovative systems of closed farming, etc.).

The government regulation of innovation processes is actualized for the Russian agricultural sector. It should cover the following directions:

- Transformation of the institutional environment, involving the development of new levers of legal regulation and the formation of an appropriate legal framework for the development of innovative technologies;
- Creation and development of new scientific schools and formation of an environment to support start-ups, venture investments, and innovations;
- Strengthening the regional component of innovation development and the development of strategic planning of innovation development of the region with the justification of mechanisms of resource provision;

- Creation of a unified information network of the AIC and regional cluster on innovative and investment development of the agricultural sector of the economy.

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Economic Efficiency of Anti-Stress and Phytohormone Preparations in Cultivation of Spring Rape in Soil and Climatic Conditions of the Republic of Tatarstan

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Abstract Ultramodern preparations Cytodef 100 and Hyberelon containing phytohormones increase the resistance of spring rape to unfavorable environmental factors. These preparations provide the formation of a dense (128 pcs. per m^2) and high stem (124 cm) and up to 38 pcs/plant productive pods with 1000 seeds weighing 3.36–3.40 g. As a result, the yield of spring rape increases by 0.38 t/ha, which is 21.8% higher than the control. Leaf feeding of spring rape in the phase of 6–8 leaves with an anti-stress Cytodef 100 preparation (200 g/ha) and Giberelon (80 g/ha) in the phase of budding of the studied crop can be combined with chemical weeding and insecticide treatments against blister beetle, which eliminates the additional costs. In this case, the profitability of oilseed rape production is close to 70%. The production cost is reduced to 12.4 thousand rubles per ton against the selling price of 21.0 thousand rubles per ton. Each hectare of rape field provides more than 18 thousand rubles of net profit.

Keywords Spring rape · Agrochemicals · Oilseeds · Value of gross output · Total costs · Profitability · Cash proceeds · Cost price

JEL codes Q15 · Q16

1 Introduction

At all times and in all countries, production and provision of the population with food has been and remains one of the priorities of public policy because food security is

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_12

the most important factor in maintaining the country's sovereignty. Agriculture is the key sector to ensure the country's food security. Unfortunately, the institutional transformations of the economy that led to the liberalization of prices, the considerable growth of imports of agricultural products and foodstuffs, and the disparity of prices for agricultural and industrial products, fuel, and lubricants significantly reduced the organizational, economic, and financial conditions of agricultural formations. These circumstances led to a decrease in the economic efficiency of agricultural production and the quality of the products produced. The growth of agricultural production in Russia in the last decade is connected with recognizing the priority of the industry by the government and the introduction of reciprocal measures by the EU countries and the Russian Federation. Implementation of state programs aimed at developing the agro-industrial sector of the economy, favorable investment climate, and budget policy allowed Russia to significantly reduce dependence on food imports and become a leading exporter of high-quality food grain. Thus, according to the Federal Service for Veterinary and Phytosanitary Surveillance of the Russian Federation (Rosselkhoznadzor), wheat exports exceeded 38 million tons in 2020, and the total grain crops exceeded 57 million tons. In the future, another important export crop will be oilseed rape because, unlike the heat-loving sunflower, it can be successfully grown from the southern outskirts of the Russian Federation to the Arctic Circle (Faizrakhmanov et al., 2013; Gaisin, 2000; Minnullin, 2003, 2008). It is also promoted by the recovery of agricultural machine-building, primary seed production of highly productive varieties of spring rape, production of macro and micro fertilizers, plant protection chemicals, the high selling price of oil-bearing raw materials (20–22 thousand rubles/t against 14–15 thousand rubles/t of spring wheat), and unlimited market (Safiollin, 2008; Safiollin & Vakhitov, 2000; Spaar et al., 1999).

However, the increase in the cost of cultivating spring rape often outpaces the increase in purchasing prices. This is primarily due to rising prices for fuel and lubricants, purchase, transportation, storage, and application of mineral fertilizers and pesticides (Nizamov, 2018; Nizamov & Suleymanov, 2020; Safiollin et al., 2020). From this point of view, the use of anti-stress and phytohormone preparations stimulating the internal reserves of the plants is an urgent problem of further increasing the production of competitive oilseeds with low production costs.

The paper aims to determine the effect of leaf-feeding of spring rape with the anti-stress preparation *Cytodef-100 VRP* combined with the phytohormone *Giberelon VRP* on the yield and economic efficiency of rape oilseed production.

2 Methods and Research Conditions

The primary research method was a field experiment conducted on typical gray forest soils of the Republic of Tatarstan. Laboratory analyses were carried out at the Center for Agroecological Research of the Agronomic Faculty of Kazan State Agrarian University. *Ruyan* variety of spring rape was placed after winter wheat, which served as an equalizing crop. The technology and methods of research were common for the

Republic of Tatarstan. Mineral fertilizers were applied under pre-sowing cultivation with the expectation of getting 2.5 t/ha of oilseeds.

The economic efficiency of the studied methods of increasing the productivity of spring rape was determined by comparing the costs with the value of gross output in prices of 2020.

3 Results and Discussion

Rape agrocenosis fundamentally differs from other crops. First, its field germination does not exceed 65%–70% compared to 85% for spring crops (Chebotar et al., 2007; Khismatullin et al. 2019a, b). Out of 250 seeds sown in our experiments, sprouts were observed in 162 seeds per m^2 (field germination—65%). Second, rape agrocenosis is more prone to self-regulation of stems. As branching increases, some plants are displaced from the agrocenosis, and the survival rate decreases to 76%–79%. Therefore, the above trends have a major impact on overall stem density before harvest.

The results of determining the density of stems also show that we cannot exclude the indisputable fact of increasing the analyzed index under the influence of anti-stress preparation *Cytodef-100* and phytohormone *Giberelon VRP*, under the influence of which the preservation of plants is 79% of the received seedlings (128 pcs. per m^2).

In this case, we can confidently say that phytohormones of these preparations increase the internal reserves of plants and increase their resistance to adverse environmental conditions (temperature and soil environment, lack of moisture, toxic chemicals used against weeds and pests, especially against rape blossom blight).

There is a direct correlation between density and stem height—the more plants per unit area, the greater their height.

Thus, a combination of *Cytodef-100* leaf-feeding for spring rape at the phase of 6–8 leaves with the application of *Hyberelon* at the phase of budding—flowering ensured the formation of agrocenosis with an average height of 118 cm. However, an increase in plant height has a contradictory effect on the weediness of spring rape crops. On the one hand, dense high-growing agrocenoses have little vital space for the growth and development of the weed community. Nevertheless, this positive effect only lasts until the pod formation phase. The pods gain much mass by the beginning of seed ripening; the plants lodge and even break. As a result, the remaining weeds occupy the upper tier by the end of the growing season and accumulate relatively large biomass.

For example, in Variant 3, the number of weeds on an area of 1 m^2 was minimal (7.0 pcs. per m^2). Nevertheless, due to the high lodging (24% according to a visual assessment), the air-dry weight of weeds was 8.5 g/m^2, which is 33% more than in control. In general, according to the scale of V. V. Isayev (Spaar et al., 1999), the weed infestation of rapeseed agrocenosis belongs to the weak group, which is explained by the chemical weeding of annual (mainly chicken millet) and dicotyledonous weeds (species of thistle and barnacle).

The weakest link in the production of rape oilseeds is the "fuse" of the flowers of this crop due to the high average daily air temperature at the end of June—the beginning of July. As a result of mass flower shedding, the number of pods is significantly reduced, which is the main reason for a significant decrease in the productivity of the rapeseed field. At first glance, it is impossible to regulate the provision of plants with thermal resources. Nevertheless, it is possible to reduce flowering due to high temperature by applying anti-stress preparations combined with gibberellin phytohormones in the budding phase of spring rape.

The results of field experiments show that the number of productive pods rose from 36 pcs/plant in control to 38 pcs/plant with foliar fertilizing of spring rape in the phase of 6–8 leaves with *Cytodef-100* (200 g/ha) and additional spraying of crops in the budding phase—beginning of flowering with *Giberelon* (80 g/ha). The other variants of the experience occupied an intermediate position. For this reason, their advantage was within the margin of error of stationary studies in the number of pods and other parameters (length and diameter).

The final result for which we grow spring rape is the gross yield of oilseeds, the value of which depends on the density of the stem before the harvest, the number of productive pods on each plant, and the filling of the pods of large seeds.

The results of the analysis of fruiting elements of spring rape allow us to distinguish the following regularities:

1. The fewer seeds in a pod, the higher their mass is and vice versa. In other words, an increase in the number of seeds is accompanied by a decrease in their mass.
2. There is a clear positive correlation between stem density and the number of pods per unit area (m^2) (the higher the first indicator is, the higher the second).
3. The combination of four indicators (stem density (m^2), the number of pods (pcs. per plant), the number of seeds in a pod (pcs.), and the weight of 1000 seeds (g)) on the third experiment variant provides the highest biological yield (2.29 t/ha), which is higher than the control by 25%.

In the variants of the experiment with double-leaf feeding (the first feeding with *Cytodef-100* and the second with *Hyberelon* or two times with *Hyberelon*), the gross yield of commercial rape oilseeds was 2.12 and 2.11 t/ha, which is 21.8% and 21.3% higher than the control. Simultaneously, on these variants, the loss of biological yield increased to 7.4–7.1% against 5.1–5.5% on other variants, including the control plot. Nevertheless, despite tangible losses, it was on these variants that the yield increase was higher than the smallest significant difference: 0.37–0.38 t/ha at HCP_{05} equal 0.21 t/ha (Table 1).

The high economic efficiency of applying anti-stress and phytohormone preparations on spring rape should be especially noted because they can be combined with the treatment of spring rape with pests, diseases, and weeds (Table 2).

The cost of gross production depends on the yield and the selling price of oilseeds. It varies from 36.5 rubles/ha for the control variant to 44.5 thousand rubles/ha in the variant with the application of *Cytodef-100* at the rate of 200 g/ha in the phase of formation of 6–8 leaves and the additional spraying of *Hyberelon* (80 g/ha) in the phase of summer rape budding.

Table 1 Gross yield of marketable oilseeds and values of biological yield losses

Variant	Yield, t/ha	Increase		Loss of biological yield, %
		t/ha	%	
Control (no treatment)	1.74	–	–	5.1
Spraying of plants in the phase of leaf rosette (6–8 leaves) with *Cytodef-100*, VRP, 200 g/ha	1.90	0.16	9.2	5.6
Spraying of plants in the phase of leaf rosette (6–8 leaves) with *Cytodef-100*, VRP, 200 g/ha and spraying of plants in the phase of budding—beginning of flowering with G*iberelon*, VRP, 80 g/ha	2.12	0.38	21.8	7.4
Spraying of plants in the phase of leaf rosette (6–8 leaves) with G*iberelon*, VRP, 80 g/ha and spraying of plants in the phase of budding—beginning of flowering with G*iberelon*, VRP, 80 g/ha	2.11	0.37	21.3	7.1
Spraying of plants in the phase of leaf rosette (6–8 leaves) with G*iberelon*, VRP, 50 g/ha and spraying of plants in the phase of budding—beginning of flowering with G*iberelon*, VRP, 50 g/ha	1.94	0.20	11.1	5.5
HCP_{05}	0.21			

Source Compiled by the authors based on their own experiments

In addition to logistics and warehousing costs for the purchase of agrochemicals, total costs include expenses for mechanized fieldwork, including the cost of harvesting additional crops and many deductions from the wage fund minus compensation payments provided by the Ministry of Agriculture of the Republic of Tatarstan and the Russian Federation (Khismatullin, 2019; Khismatullin et al., 2017, 2021a, b; Safiollin et al., 2021).

Calculations considering all items of costs show the growth of total costs from 23.7 to 26.2 thousand rubles/ha with the growth of spring rape yield from 1.74 t/ha on the control (without application of studied preparations) to 2.12 t/ha on Variant 3 (Khismatullin et al., 2019a, b; Lukmanov et al., 2021; Mukhametgaliev et al., 2020). However, the maximum net profit from one hectare of arable land (18.3 thousand rubles) was received exactly on this variant of the experiment, and the profitability of oilseed rape production was 69.8% against 54.0% on the control.

Table 2 Economic indicators of application of anti-stress and phytohormone preparations on spring rape crops

Variant	Gross product value, thous. RUB/ha	Total costs, thous. RUB/ha	Net profit, thousand rubles/ha	Profitability, %	Cost, thous. RUB/t
Control (no treatment)	36.5	23.7	12.8	54.0	13.6
Spraying of plants in the phase of leaf rosette (6–8 leaves) with *Cytodef-100*, VRP, 200 g/ha	39.9	25.0	14.9	59.6	13.2
Spraying of plants in the phase of leaf rosette (6–8 leaves) with *Cytodef-100*, VRP, 200 g/ha and spraying of plants in the phase of budding – beginning of flowering with G*iberelon*, VRP, 80 g/ha	44.5	26.2	18,3	69.8	12.4
Spraying of plants in the phase of leaf rosette (6–8 leaves) with G*iberelon*, VRP, 80 g/ha and spraying of plants in the phase of budding—beginning of flowering with G*iberelon*, VRP, 80 g/ha	44.3	26.0	18.1	69.1	12.4
Spraying of plants in the phase of leaf rosette (6–8 leaves) with G*iberelon*, VRP, 50 g/ha and spraying of plants in the phase of budding—beginning of flowering with G*iberelon*, VRP, 50 g/ha	40.7	25.8	14.9	57.8	13.3

Source Compiled by the authors based on their own experiments

4 Conclusion

Spraying of spring rape leaves with anti-stress *Cytodef-100* and phytohormone *Giberelon* provides 8.6 thousand rubles of cash proceeds from selling each ton of oilseeds (from the selling price of 21 thousand rubles/t we subtract 12.4 thousand rubles—the cost of production of one ton of raw oilseed rape).

Thus, leaf-feeding of spring rape in the phase of 6–8 leaves with *Cytodef-100* at a rate of 200 g/ha in combination with the use of *Giberelon* (80 g/ha) during the budding phase and the beginning of flowering has a great practical and economic significance in the production of competitive oilseeds with low cost and profitability of about 70%. The production cost is reduced to 12.4 thousand rubles per ton against the selling price of 21.0 thousand rubles per ton. Each hectare of rapeseed field provides more than 18 thousand rubles of net profit.

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The Current Problems of Agriculture and the Perspectives of Their Resolution Based on AgroTech

Quality as an Integral Component of the Reproduction of Technical Resources in Agriculture

Elena V. Kovaleva

Abstract The paper focuses on the theoretical provisions of quality as an integral part of reproducing technical resources in agriculture. The specific features of reproduction in agriculture were revealed during the analysis of the problems and views of scientists on the reproduction of resources in agriculture. The process of reproduction is cyclical. The cyclicality of reproductive processes is considered taking into account the changing quality. The authors identified three levels of development of reproduction processes to improve the efficiency of reproduction processes on a qualitatively new scientific and technological basis. The paper determined that at the present stage of development the reproduction in agriculture should proceed with the use of digital technologies.

Keywords Quality · Reproduction · Resources · Technical resources · Digitalization

JEL Codes Q13 · Q18 · O13 · L15

1 Introduction

Tasks of reproduction processes organized on a qualitatively new scientific and technological basis (advanced information technology), which would provide an increase in efficiency of all production, should be solved primarily by accelerating scientific and technological progress, ensuring extensive practical use of discoveries, inventions, and the latest advances in technology, and considering the specific features of reproduction in agriculture through a targeted selection for the introduction of the most efficient production means based on the assessment of their performance and quality.

In a socially-oriented society, product quality is an objective of direct satisfaction of the consumers of goods in accordance with their demands formed during the use of material and other goods. The market economy defines ways to improve

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_13

product quality through the business goal of maximizing profits, which is achieved by conquering the sales market and consumers with the quality of products increasing faster than the growth of prices.

According to Marx's theory of utility, value, leaving aside its purely symbolic expression in the sign of value, exists only in certain use-value, in a particular good. "Since a commodity is purchased by the buyer, not because it has value, but because it is 'use-value' and is used for specific purposes, it is completely self-evident, (1) that use-values are 'assessed,' i.e., their quality is investigated (just as their quantity is measured, weighed, etc.); (2) that if different sorts of commodities can be substituted for one another in the same useful employment, this or that is given preference, etc." (Marx, 2010, p. 245).

From these positions, the quality of goods should be assessed given their interchangeability for the same consumption purposes to give preference to the product (its quality) that provides the greatest efficiency of the subsequent application.

Thus, from the production to the beginning of consumption and during it, the product does not retain its original properties, and the quality changes adequately to the change of these properties. This fact necessitates the tracking of quality dynamics. The instability of the properties of goods affects the assessment of their quality and changes the vector of interchangeability.

Different definitions of quality can be found in the literature, each with its own characteristics. According to Aristotle, who first studied quality as a philosophical category, qualities are those "by which objects are called so-and-so," it is quality that determines the properties of an object (Aristotle, 1999). Kant continued the study of quality and compared it with quantity in more detail (Kant, 1964).

The variety of existing definitions of quality by K. Hegel, K. Marx, and F. Engels (Marx, 1867); Deming (2007); Juran (2004); Crosby (2003), Feigenbaum (1986); Taguchi et al. (2004); Harrington (1990); Azgaldov (1982); Ogvozdin (2009) and other scholars and specialists testify to the debatable nature and confirm the relevance of the problem of quality for the development of science and the activities of enterprises and the country.

A certain uniformity in the interpretation of the concept of quality is defined in the terminological GOST (Russian national standard). The quality of products is a set of properties that determine the suitability to meet certain needs in accordance with its purpose (GOST 15467-19 (ST SEV 3519-81) 1979).

The problem of quality is multidimensional. It covers all aspects of economic activity. The quality of technology, especially the quality of tools, determines the quantity and quality of products and work performed with their help, the number of raw materials consumed in the production process, and the amount of waste. Moreover, the quality of technology determines the cost of public labor for the production and application of the entire mass of products manufactured with its help.

In practice, there are different interpretations of the concept of "technical quality." In a broad sense, it is understood as a set of properties indicating the technical level of the products of a particular type. This includes the operational, consumer, production, technological, and aesthetic properties (e.g., carrying capacity, speed, weight, the

labor intensity of manufacturing, processability, reliability, durability, and aesthetics of the car). Together, these properties define the place of this type of equipment among products with similar purposes, both domestic and foreign.

Comparing the level of products manufactured with the current technical level allows giving a correct assessment of quality and outlining the right ways to achieve the level of the best world samples in the shortest time possible.

The rapid pace of scientific and technological progress leads to the fact that the current technical level, by which the quality of manufactured products is judged, can become obsolete very quickly.

In a narrower sense, the concept of technical quality includes a set of properties determining the suitability of the product for its intended use. This includes only operational and consumer properties (e.g., load capacity, speed, engine power, reliability, and durability of the car).

In practice, one can encounter an even narrower interpretation of the quality of technology, which refers to the operational and consumer properties of products that do not differ in their specific indicators. For example, machines with several identical indicators (e.g., load capacity, weight, speed, engine power, efficiency, etc.) differ in the degree of reliability and durability.

The research aims to adjust the cyclicity of reproduction processes considering the changing quality and efficiency of reproduction processes on a qualitatively new scientific and technological basis (advanced information technology) based on the analysis of theoretical provisions of quality as an integral part of the reproduction of technical resources in agriculture.

2 Methods

The economic importance of the quality of technology lies primarily in the following:

- The technology of a certain quality is created at a certain cost of public labor;
- The achievement of a better quality of technology often requires an increased expenditure of labor and capital to produce it;
- The use of technology involves a certain expenditure of public labor to maintain the quality of technology at the level that was set at the time of manufacture;
- By regulating the quality of machinery in its manufacture, one can change the cost of public labor to operate it.

New machinery, devices, apparatuses, and materials differ from traditional ones not only in their production costs but also in their higher quality (i.e., performance, service life, and specific material consumption). Despite the diversity of types of equipment and manufacturing and operating conditions, they all have common requirements, one of which is the requirement to have a certain ability to work.

Inadequate machinery cannot be used effectively for its intended purpose, and the cost of its manufacture is a waste of public labor.

No matter how technically advanced the equipment is, it cannot be functional indefinitely. After some time, the operation is forced to stop due to equipment malfunction or unacceptable deviations from the parameters set. To continue the production process, the equipment must be restored to serviceability or replaced if it cannot be restored to serviceability. Technical products (e.g., parts, machines, assemblies, etc.), the functionality of which cannot be restored, are single-action products (e.g., electric lamps, rolling bearings, some types of tools, etc.) or non-recoverable products.

Most types of equipment designed for long-term operation (considering the restoration of performance during operation) are restorable products. However, in the course of the long-term operation of the equipment, such restoration may not be possible due to technical or economic reasons; in this case, the equipment must be replaced. Thus, the operability of the equipment is always limited to a certain time and amount of work to be performed.

For equipment to serve its purpose, it must operate properly for the specified time and under the appropriate operating conditions. This requirement, which is common to all types of equipment, corresponds to the general quality indicators (e.g., reliability and durability).

From the correlation between reliability and specific indicators of technical quality, it follows that the latter cannot be ensured during operation without a reliability indicator.

The requirement of reliability in operation is imposed on any type of equipment regardless of its purpose. Therefore, reliability is the most general indicator of quality. Reliability in operation becomes the most important indicator of quality for many types of equipment, the failure of which can lead to serious consequences.

A certain amount of human and social labor is required to restore the serviceability of unreliable equipment. Therefore, the more reliable the equipment is, the lower the costs associated with maintaining it at a given level and restoring its performance. Improving the machinery reliability means reducing the cost of public labor to operate it.

The concept of reliability mentioned above is the most general and applies to all types of equipment. Specifying it in relation to different types of equipment, let us define the criterion of their reliability. Thus, for some types of equipment (e.g., vehicles, emergency alarms, etc.), the most important measure of reliability is the absence of sudden (emergency) failures during the warranty period; for control and measurement instrumentation—maintaining its stability, accuracy, and timeliness of readings.

For most types of technological equipment, the reliability criterion is understood in the sense of stability of operating parameters for a given time.

To determine equipment reliability, it is necessary to have its quantitative expressions—measures (indicators) of reliability. Each reliability criterion has its own quantitative indicators.

3 Results and Discussion

With the further development of economic doctrines on the reproductive process, it is possible to formulate some current characteristics inherent in it. The reproduction process is cyclical, with alternating production, exchange, distribution, and consumption (Fig. 1).

The process of reproduction of agricultural machinery must provide the highest possible rate of increasing productivity of public labor, which can only be achieved by a targeted selection for the introduction of the most productive machinery based on the evaluation of their performance and quality.

Currently, society uses equipment of various technical and economic levels. The efficiency of improving particular parameters of equipment was not considered in previous methodologies; the equipment no longer corresponds to its initial indicators laid down in the design. However, it is no longer possible to determine the technical level of obsolete equipment necessary for the organization of productive consumption

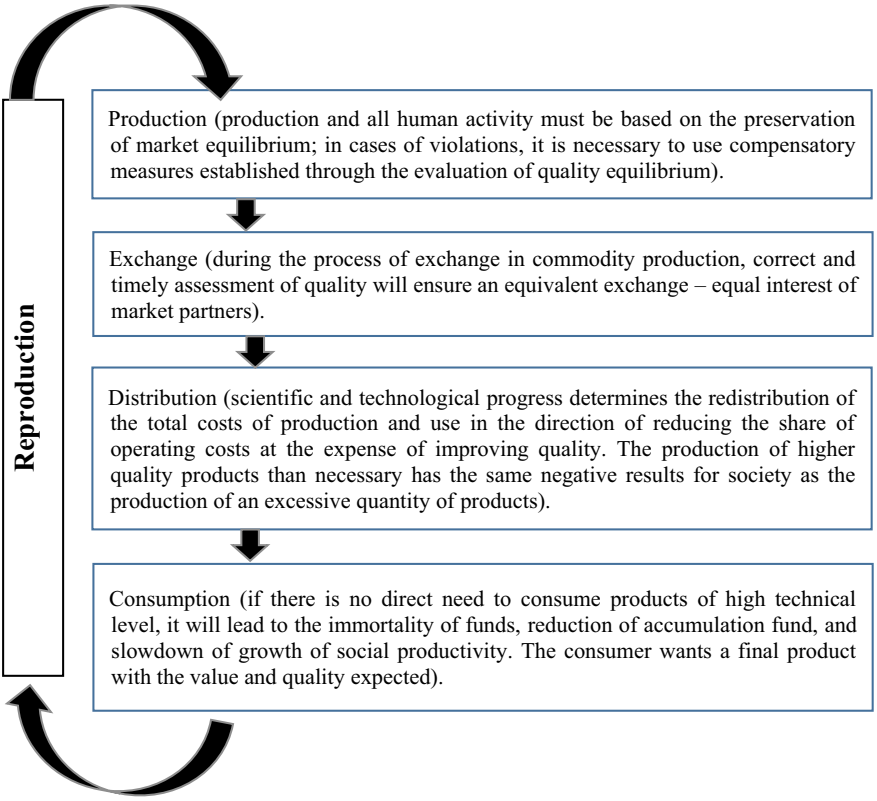

Fig. 1 Cyclicality of reproduction processes, considering changing quality. *Source* Compiled by the authors

using the old parameters (Kovaleva, 2020a). In the agricultural sector, the government conducts pricing policy and is engaged in forming and realizing the potential of particular branches. The issues on the organization of expanded reproduction are solved by agricultural producers themselves, such as the organization of introduction of new equipment, development of repair base, and specialization and cooperation of production. In this regard, it is advisable to distinguish three levels of development (Fig. 2).

At the first level of development of the reproduction processes, there is full use of resources. The resources are limited, so is the result of their use. The efficiency of the reproduction will not be permanent but may be quite effective in a crisis temporarily.

Considering the quality of the reproduction process, the second level is marked with an increase in labor productivity, a decrease in cost intensity per unit of output, and, consequently, an increase in production efficiency. There is economic growth and an influx of investment in the reproduction of resources.

The third level is the Russian agro-industrial complex, an intensively developing industry. Most agro-industrial enterprises of the Russian Federation have reached a new (third) level of efficiency, which was essentially assisted by advanced information technology and means of production automation.

The economic benefit of large-scale production for enterprises is evident: the personnel reduction provides stable and manageable quality of products, a well-organized rhythm of supply and shipment of products, and the minimum time to reach the planned production parameters (Table 1).

This effect is achieved through the synergy of informatization and automation of business processes. Information systems are implemented throughout the enterprise and integrated with robotic lines and machinery.

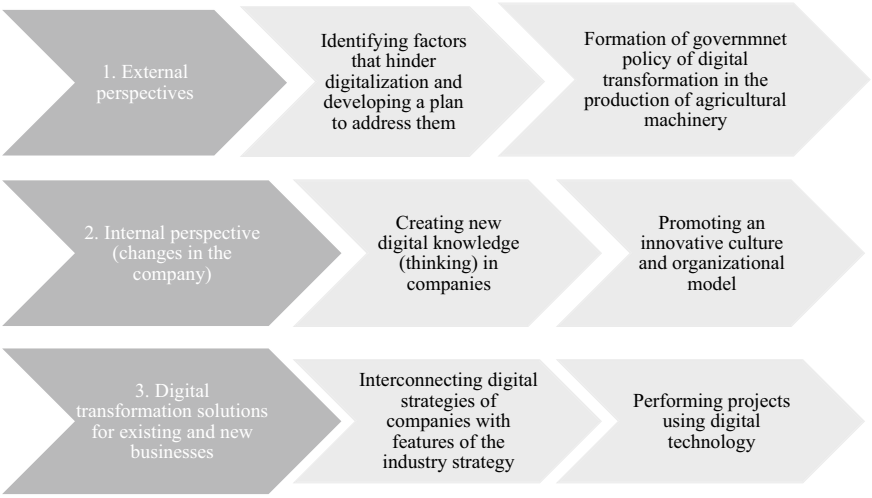

Fig. 2 Directions and step-by-step actions to implement the mechanism of digital transformation of the reproduction process in agriculture. *Source* Compiled by the authors

Table 1 Efficiency of reproduction processes on a qualitatively new scientific and technological basis (advanced information technology)

Level of the reproduction process	Efficiency of the reproduction process	Moving from one level to the next one
The first level of development	It is effective in times of crisis to ensure food security and create an optimal level of supply of goods on the market	It cannot be momentary and must be gradual and step-by-step
The second level of development	At this stage, there is economic growth and an influx of investment in the reproduction of resources, the efficiency of production increases; there is an increase in labor productivity	
The third level of development	It emerges with the application of qualitatively new digital information for simulation modeling of business processes. This level of development is due to the use of advanced end-to-end informatization technologies, digital twins, and ERP platforms in the production of equipment	

Source Compiled by the authors

For an agro-industrial enterprise of any organizational and economic form, the totality of machine and tractor and labor resources determines its ability to receive income from newly created products, determine its monetary value, and compare production costs with the income (Kovaleva, 2020b).

The current stage in the development of the reproductive process requires large-scale changes due to the transformation and change in technological processes caused by the rapid introduction and application of digital information in the production of equipment.

Transformations in the application of new technologies in the production of agricultural machinery and equipment and their conversion to the digital format of functioning create fundamentally new, previously unused economic and managerial relationships that require the use of distributed registry tools of digital data and information.

Simultaneously, the process of digitalization is carried out against the background of structural changes in production technologies, staffing, and corporate culture. These factors must be considered in the reproduction of machinery and equipment to improve their quality.

Thus, there is a need for scientific understanding, study, and development of the mechanism of implementation (adaptation) of digital transformation in the process of reproduction of agricultural machinery.

The first thing is to define directions and step-by-step actions to implement the mechanism of digital transformation. We propose to define three main directions (Fig. 2).

The first direction is the formation of external perspective conditions. This step identifies the factors that hinder digitalization and develops a plan to eliminate them. Consequently, this should be the basis for the formation of government policy in the field of digital transformation in the agro-industrial production of machinery and equipment.

The second area of the digital transformation mechanism is determined by internal perspectives (changes in the company). At this stage, it is necessary to create a new digital mindset in enterprises. This will promote a culture of innovation and form an appropriate organizational model for the digital transition.

The third direction is appropriate to establish digital transformation solutions for existing and new businesses. This task is proposed to be solved by linking the digital strategies of companies with the peculiarities of industry policy. This consolidation will result in implementing projects to develop the reproduction of machinery and equipment in agriculture using digital technology.

During the implementation of reproduction processes of equipment and agricultural machinery with the use of digital technology, there is some standardization and unification of transformations and functions of reproduction processes, i.e., the development is marked with the transition from the natural study of the development process to the model study (Puzyrny et al., 2019).

Simultaneously, it is necessary to consider that developing systems are characterized, on the one hand, by the stability of the structure and, on the other hand, by the loss of stability, the destruction of one structure, and the creation of another stable structure. Thus, the reproduction process appears as a sequence of cyclic evolutionary change of states within a cycle, with a jump-like transition of the state at the end to a new qualitative level, signifying the beginning of a new cycle of digital integration in the development of reproduction. In other words, it is an iterative process. A consequence of cyclical development (with a "jump" at the end of the cycle to a qualitatively new level) is irreversibility, the impossibility of transition from a newly formed structure to the old destroyed one.

A perfect concept is a representation of enterprise development as an iterative process, i.e., a cyclical process in the course of which the state of reproduction is improved using advanced artificial intelligence technologies.

4 Conclusion

1. The reproduction process is cyclical in nature, in which production, exchange, distribution, and consumption alternate. Cyclicity of reproductive processes should be considered in the light of changing quality;

2. Improving the efficiency of reproduction processes on a qualitatively new scientific and technological basis defines three levels of development; the transition from one level of development to another must be gradual and cannot be immediate;
3. The process of reproduction in agriculture at the present stage of development should proceed with the use of digital technologies.

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Environmental and Economic Problems of Using the Biofuel Market

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Abstract *Purpose* The purpose of this article is to identify environmental and economic problems of using the biofuel market based on the analysis of the domestic and international experience of developed countries, to show a steady trend in the development of industrial production of pellets as one of the most progressive and consumed types of biofuels. *Design/methodology/approach*: The authors use analytical, index and comparative analysis methods to determine the nature of changes in the development trend of industrial pellet production in 2020 as compared to 2016. The objects of the study are the states of the Asia–Pacific region (APR). *Conclusions*: It has been established that all countries of the Asia–Pacific region, following the requirements of the signed and ratified Paris Climate Agreement, are forced to work to reduce their carbon footprint in the Earth's atmosphere. As the energy strategies of Japan and China show, an important part of the struggle for "climate neutrality" within the framework of the national economic complexes of the countries of the region will be to reduce the role of coal in the supply of thermal power plants, due to an increase in the share of solid wood biofuels. *Originality/value*: Based on the analysis of the dynamics of statistic indicators, global trends in the production of wood pellets in some countries in the Asia–Pacific region and their exports are reflected. The Asia–Pacific biofuel market is very promising for Russia, primarily for timber companies located in the Far Eastern Federal District. The ecological and economic

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_14

problems of biofuel production and use are reflected. A system of evaluation indicators is proposed, attention is focused on reducing environmental and economic problems in this area due to the innovative development of the timber industry, effective marketing and financial activities, as well as the readiness of Russian biofuels to enter the world market.

Keywords Timber industry · Environmental and economic factors · Biofuels · Pellets · Growth criteria

JEL Codes L11 · L16 · L17 · L65 · L73 · O11 · O13 · Q16 · Q35 · Q53 · Q57

1 Introduction

The main problem of the Russian economy is the high energy intensity of all types of industries. If we use for the analysis the indicators of the specific energy intensity of GDP in the Russian Federation in comparison with the countries of Western Europe, then Russia consumes energy three times more. Unjustified and ill-considered decisions to split the unified energy system of the Russian Federation, the absence for a long time of the state policy and energy-saving program, the depletion of energy resources put the energy problem as a priority one for the economy of the Russian Federation.

In real practice, the support of an increasing number of countries for climatic requirements has sharply raised the question of the future of one of the most important spheres of the economy—energy. In turn, this has caused rapid development of R&D in the field of searching for new energy sources, which should simultaneously have the least possible negative impact on the environment and be accessible to as many national economic complexes as possible. One of the results of these studies was the revival of the processes of production and consumption of fuel based on forest plant components.

For a long time, forest fuel was the main source of energy for mankind, which was used both for heating homes and in economic activities. But with the beginning of the era of three successive industrial revolutions, wood fuel became a symbol of backwardness and was widely used only in the poorest countries of the third world. Nevertheless, in connection with the conclusion, in line with the UN Framework Convention on Climate Change, such agreements as the Kyoto Protocol of 1997 and the Paris Agreement of 2015, which postulate the need to reduce carbon dioxide emissions, the question of new environmentally friendly energy sources has become acute.

Russia is a northern country and the problem of heat power engineering concerns the well-being of its entire population. First of all, this concerns the housing and communal services of municipalities, since as a result of the wear and tear of utility networks, the cost of energy resources and the number of energy losses are sharply

increasing by up to 60%. A side disadvantage is an environmental degradation and environmental pollution.

Many authors single out (Argus Biomass Market, 2021; By, 2030; Grigoriev 2020; Krivokochenko, 2021; Kunitskaya et al., 2021a; Paris Agreement, 2021; Pellets, 2021) the key factor is ecological, especially in the forest sector, due to the functions of the forest. Other authors research trends in the Russian and world biofuel market, study what support measures and incentives for the development of bioenergy can be attracted for a Russian manufacturer. Numerous works of such authors as (Kunitskaya & Pomiguev, 2021a, b; Kunitskaya et al., 2020, 2021a, b, c) are devoted to the theoretical substantiation of the problem and the analysis of the process of briquetting crushed wood materials in a forest terminal. No less significant are the scientific studies of Grigoriev; Kunitskaya et al., 2020; Morkovina et al., 2021) in the framework of improving the optimization of technical systems.

Specialists in the field of economic research of the problem (Bezrukova et al., 2021; Butko, 2020; Petrov, 2020) focus their attention on the problem of rational forest management, an effective approach to the sources of raw materials. Foreign authors (Dolah et al., 2021; Jaiswal et al., 2021; Niu et al., 2013) reflect the advantages of biofuels and alternative energy sources in the context of a shortage of natural raw materials in the format of the coming third decade of the twenty-first century.

According to the authors, an assumption is made about the influence of the environmental factor on the final cost of the enterprise. To test the hypothesis put forward we will build a model of interaction between the growth of the enterprise value, depending on its environmental component.

2 Materials and Methods

Problems and prospects for the development of industrial production of progressive and consumable types of biofuels, their ecological and economic features for the timber industry complex in Russia and foreign countries are studied in the scientific works of (Butko and Zotov, 2016; Butko, 2020; Dolah et al., 2021; Grigoriev; Grigorieva & Nguyen, 2017; Jaiswal et al., 2021; Krivokochenko, 2021; Kunickaya et al., 2020; Kunitskaya & Pomiguev, 2021a, b, c; Kunitskaya et al., 2020, 2021a, b, c, d; Makar, 2018; Morkovina et al., 2021; Nguyen & Grigorieva, 2016; Niu et al., 2013; Niu et al., 2010; Paris Agreement et al., 2021; Petrov, 2020; Pomiguev et al., 2021; Vlasov & Kunitskaya, 2021); reflected in official documents (Argus Biomass Market, 2021; Asia's Energy Sector, 2021; By, 2030; Consumption of Wood Pellets, 2021; Export to Japan or South Korea, 2021; Forestry Production and Trade, 2021; Pellets, 2021; Prospects for the Sale of Pellets to Asian Countries, 2021; Russia's Energy Strategy, 2003; The Consumption of Pellets in Asia, 2021).

The initial materials are the scientific approaches of Russian and foreign scientists. The article used such methods as analytical, comparative, index analysis, logical and mathematical modelling, and tools for systematizing occurring phenomena.

Speaking about the latest trends in the wood pellet market, it is worth referring to the report of the British agency ArgusBiomassMarkets (Dolah et al., 2021). The spot price for the shells of Indonesian palm kernels used as a resource for the production of pellets, as well as the price of their delivery, increased. Vietnamese shipments, mainly from Ho Chi Minh City, have not returned to pre-pandemic levels. The spot price of industrial wood pellets in Vietnam rose 91 cents/tonne to $115.69/tonne, while the price when sold to South Korea jumped $1.72/tonne/week to $135.50/t. Material supplies for factories are limited, as in Indonesia. Supply also remains below the pre-pandemic level in Malaysia, where manufacturing activity in this sector remains at about 50% compared to 2019 (Dolah et al., 2021).

For the rational use of biofuels, it is necessary to study the investment attractiveness in two areas: "Assessment of the company's shareholders"; "Assessment of the market position".

To carry out an analytical assessment of strategic effectiveness, the Spearman method and its coefficient are used; a method of comparing results based on a comparative assessment of a set of the following indicators: T—the growth rate of the indicator (%); PE—net profit, PP—profit from sales; BP—sales proceeds; DZ—accounts receivable; CC—the total cost of sales; ZP—payroll.

The degree of conformity of the actual structure of the initial base in comparison with the reference one is established:

$$\text{TPE} > TPP > TBP > TDZ > TCC > TZP \tag{1}$$

The reference series of growth rates of the organization's development indicators corresponds to a rational strategy for the use of biofuels, the actual series for comparison is determined sequentially. At each stage, the absolute indicators of the financial and economic activities of the organization are summarized.

The internal rate of return as a criterion is defined as follows:

1. The value of the reduced cash flow and the net present value are determined for the rate $i = 10\%$ (at the rate of return on capital) for $n = 6$ years:

$$D = 1(1 + i)n = 1(1 + 0.1)^6 = 0.564 \tag{2}$$

2. The cash flow in the present value is determined by the algorithm (up to the first negative value of the net present value):

$$\sum F2(t) \times D = 1(1,272 + 1,370 + 1,609 + 1,632 + 1,932 + 1,930) \times 0.564 \tag{3}$$

3. The NPV is determined for each betting option.

Interest rate, % Discount multiplier "Cash flow in real value", is determined as a difference:

$$NPV = (\text{CF} - \text{IF}) \times Tin \tag{4}$$

where *Tin* is the rate of innovation growth of biofuels;

CF—the amount of cash flow (in real value) for the entire period of operation of the investment project (before the start of new investments in it);

IF—the amount of investment funds allocated for the implementation of an investment project.

3 Results and Discussion

The timber industry complex (LPC) of Russia is a promising direction for the development of the Russian economy: it produces 5.6% of the country's gross output (Butko & Zotov, 2016), provides 12% of the state budget funds, without fully using its potential (Argus Biomass Market, 2021; Asia's Energy Sector, 2021; Bezrukova et al., 2018).

According to the "Energy Strategy of Russia for the Period until 2020" (Russia's Energy Strategy, 2003) "gas prices in 2015 increased by 3 times. In terms of the calorific value, the cost of gas will be 1.2–1.3 times higher than the cost of coal. In connection with the constantly increasing cost of fuel oil, diesel fuel, coal and natural gas, there is an urgent need to create a regional fuel industry based on local energy resources".

Raw materials for the production of biomaterials to replace natural resources are "logging waste, sawdust, wood chips, shavings, lump waste and bark, small-scale timber from thinning. The use of this potential will make it possible to fully provide heat and electricity to most municipalities in remote forest areas that do not have centralized energy sources" (Prospects for the Sale of Pellets to Asian Countries, 2021). Using them for incineration is a promising direction.

A feature of solid wood biofuel is its low cost and ease of production, and the ability to use woodworking waste and non-commercial wood as a resource. Solid biofuels are very convenient for long-distance transportation, wood pellets and briquettes are less demanding on storage conditions. All this makes solid wood biofuel one of the most promising sources of green energy on a global scale (By, 2030).

Biofuel markets are largely related to the markets of eco-sensitive countries, for which the renewability of this resource is important (Butko & Zotov, 2016). In many countries of the world, the targeted cultivation of energy wood on forest plantations is very common (Butko, 2020). In this case, fuel chips from energy wood are usually obtained directly at the site of its harvesting (Petrov, 2020).

Some authors believe that the main types of wood biofuels are fuel pellets and briquettes (Dolah et al., 2021; Grigoriev; Grigorieva & Nguyen, 2017; Jaiswal et al., 2021; Krivokochenko, 2021; Kunickaya et al., 2020; Kunitskaya & Pomiguev, 2021a, b, c; Kunitskaya et al., 2020, 2021a, b, c, d; Makar, 2018; Morkovina et al., 2021; Nguyen & Grigorieva, 2016; Niu et al., 2010, 2013; Pellets, 2021). Pellets, as a rule, have higher margins for large production volumes, but at the same time they also require large investments in equipment, as well as more competent personnel.

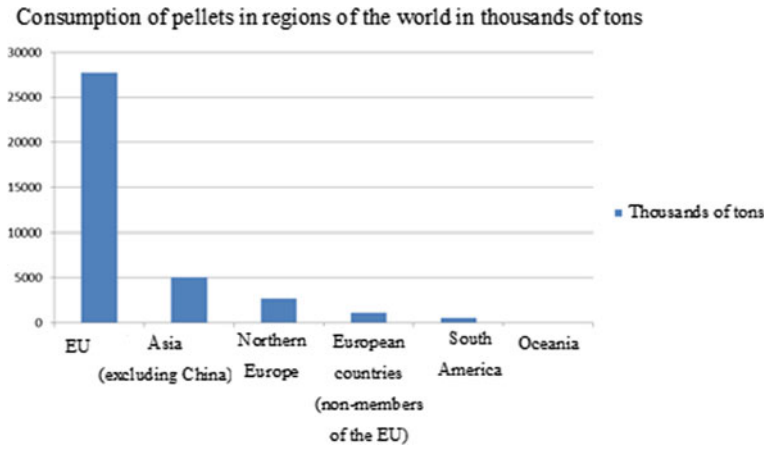

Fig. 1 Consumption of pellets in the regions of the world (thousand tons) for 2019. *Source* Compiled by the authors based on (By, 2030)

In terms of the prospects for wood biofuel, its capabilities in the Asia–Pacific region (APR) are becoming extremely important (Fig. 1). At the moment, Asia ranks second after the countries of the European Union but lags behind them.

A densely populated and industrialized region, the Asia–Pacific region is currently lagging behind Europe in terms of biofuel consumption and production but has great prospects. Soon, the capacity of the pellet market in Asia will be 50% of the global consumption (Butko, 2020). With all countries in the region signing and ratifying the Paris Climate Agreement, they will have to work to reduce their carbon footprint in the Earth's atmosphere. As the energy strategies of Japan and China show, an important part of the struggle for "climate neutrality" will be to reduce the role of coal in the supply of thermal power plants by increasing the share of solid wood biofuel. This once again demonstrates the relevance of this study (Billand et al., 2019; Export to Japan or South Korea, 2021). This conclusion is confirmed by the growing trend in the production of wood pellets in the Asia–Pacific region (APR) and its export (Tables 1 and 2).

From the above table, it can be seen that in quantitative terms, the main pellet producers in the Asia–Pacific region are the USA, Canada and Vietnam. The smallest production volumes are in Japan, Indonesia and Malaysia. USA and Canada receive the largest income from exports, but Russia and Vietnam are catching up. Japan and the Republic of Korea are strong net exporters (Table 2).

Solid fuels according to the European standards Pre-Normpr CEN/TS 14,961 are divided into groups according to the method of production, firewood, pellets, briquettes are referred to as the important group of woody biomasses. The use of bark as fuel is especially important in the context of the progress of the world market for wood fuel pellets (Argus Biomass Market, 2021; Forestry Production and Trade, 2021; Pellets, 2021; The Consumption of Pellets in Asia, 2021).

Table 1 Production of wood pellets in a number of states in the Asia–Pacific region (thousand tons)

The APR state	2016	2017	2018	2019	2020
Canada	2,889	2,906	3,048	3,020	3,830
China	485	873	873	873	873
Indonesia	90	140	290	160	160
Malaysia	370	530	710	710	710
Russia	1,290	1,680	1,411	1,845	1,965
USA	6,393	6,900	7,468	8,592	8,412
Vietnam	1,350	1,647	3,050	3,100	3,100
Japan	126	126	125	125	125
Republic of Korea	120	68	188	243	243

Source Compiled by the authors based on (Prospects for the Sale of Pellets to Asian Countries, 2021)

Table 2 Export of wood pellets from a number of states in the APR region (thousand dollars)

The APR state	2016	2017	2018	2019	2020
Canada	308,965	305,562	377,762	376,891	405,779
China	4,159	1,530	869	3,161	3,161
Indonesia	7,109	12,478	40,459	26,777	26,777
Malaysia	29,526	57,912	95,430	85,403	85,403
Russia	107,949	142,579	186,166	266,319	290,317
USA	612,496	666,545	809,855	942,627	981,593
Vietnam	119,746	172,263	361,676	309,315	309,315
Japan	46	44	57	54	54
Republic of Korea	8	1	375	18	18

Source Compiled by the authors based on (Prospects for the Sale of Pellets to Asian Countries, 2021)

For Russia, the biofuel market of the Asia–Pacific Region (APR) is very promising, primarily for the forestry companies located in the Far Eastern Federal District. Pellet production in Russia in the first half of 2021 increased by 16.5%, with almost half of exports going to Denmark, the main Asian client—the Republic of Korea, only in seventh place. Nevertheless, the process of entering the APR market is proceeding very successfully, as South Korea doubled, from 90 to 180 thousand tons, the purchase of Russian pellets. The Russian Far East possesses large forest resources and the shoulder of supplies to the APR countries, primarily to the most promising markets of the Republic of Korea, Japan and the PRC, is shorter than that of most competitors, which is also a serious competitive advantage. The federal and regional authorities should, through the creation of a system of preferences, stimulate not only the creation of new enterprises aimed at the production of solid biofuels

but also the development of waste processing into pellets at already existing woodworking plants. Without government participation, it will not be possible to achieve a significant increase in the production of pellets for supplies to the APR market, since Asian competitors, primarily Vietnam, produce products at lower prices. Thus, in the port of South Korea, the price of fuel pellets reaches $115 per ton, and in the port of St. Petersburg, the price is about $136.88 per ton, which even covers the cost of transporting cargo from the Far East to the North-West of Russia. To master the Asia–Pacific market, it is necessary to more actively develop the forest resources of the Russian Far East region (Bezrukova et al., 2018).

At present, the PRC is the main energy consumer on a global scale. China produces about 873 thousand tons of wood pellets per year, exclusively for domestic use (Bezrukova et al., 2018, 2020). Japan is one of the most promising markets for Russian wood biofuel (Butko, 2020). In 2020, Japan planned to gradually abandon fossil fuels, primarily coal. The country annually consumes about 1.5 million pellets. The main problem in Japan is the lack of internal resources for the production of relevant products. In 2020, only 125 thousand tons were produced. Japan is forced to rely on exports (Argus Biomass Market, 2021; Bezrukova et al., 2021; Butko, 2020).

Another promising solid biofuel market in the Asia–Pacific region is South Korea, in tenth place in terms of electricity consumption in the world (Prospects for the Sale of Pellets to Asian Countries, 2021). South Korea produces 243 thousand tons of pellets per year and there are plans to increase the volume, but this is not enough, and up to 80% of the country's demand for solid biofuels is covered by imports. So, according to forecasts, by 2030 the demand for pellets in this country will reach 7 million tons (Bezrukova et al., 2020; Butko & Zotov, 2016).

Innovative activity is formed much in advance before the onset of the scientific and technological reserve based on the proposed author's approach.

4 Conclusion

It is proposed to focus attention in order to effectively manage long-term sources of financing to solve the problem of creating solid biofuels on the use of the following system of indicators: the promised return on borrowed capital; the expected return on borrowed capital.

Approbation of the influence of capital structure on the cost of the solid biofuels can be performed based on the Modigliani–Miller method. The logic of actions for managing financial balances of funds is based on the Miller-Oppa model, which allows calculating the opportunity costs of keeping funds in the current account. It is advisable to represent the change in cash balances according to the Baumol model.

The solution to the problem of low demand for timber industry products in the Russian Federation in the country and the world market is justified by the innovative development of the industry, the ability and ability to produce highly competitive products for consumption in the domestic and foreign markets. The high quality of products, its low cost, effective marketing and financial activities, and the willingness

to enter the world market will allow us to fix our status in the market, as well as to constantly increase the share of woodworking enterprises.

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Assessment of Trends in Financial Indicators of State Support for the Agricultural Sector in the Context of Integration Interactions

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Abstract The agricultural sector of the economy plays a significant role in ensuring the food independence of the state. In the context of integration and international competition, risks and dangers for the stable development of the Russian agricultural sector of the economy are growing significantly. Therefore, a radical work of agricultural production is possible only with active assistance from the state at the national and regional levels. The creation of criteria for the sustainable development of agricultural lands, forcing the growth rate of the size of agricultural production on the basis of increasing its competitiveness must represent the most important course of the country's agrarian financial policy. The purpose of this topic is to activate financial indicators of state support for the agricultural sector in the context of integration processes. The scientific interest of the study is innovative financial instruments in the mechanism of development of the agricultural sector. For the evidence base of the study, official data from the Bank of Russia, the Ministry of Agriculture of the Russian Federation, data from the financial statistics of the EAEU were used. It is concluded that the main problem in the study area is insufficient funding for this segment. The authors prove that the mechanism for increasing subsidies for insurance premiums against the risk of loss or death as a result of emergencies, the formation of sufficient insurance reserves within the framework of the association of insurers; development of additional programs and tools for agricultural insurance, considering segmentation, leasing, concessional lending, are necessary.

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_15

Keywords Agricultural sector · State support · Lending · Insurance · Leasing

JEL Codes O14

1 Introduction

When implementing the state program, a number of issues remain: reduction of investments in agriculture; reduction of financial support for measures of state assistance for the development of agricultural production; low level of profitability and high degree of debt load of agricultural producers; significant dependence on the import of seed, planting and breeding material; lack of reclaimed land; insignificant rates of involvement of unused agricultural lands into circulation; lack of provision of agricultural companies with agricultural machinery and equipment; high level of depreciation of fixed assets in agriculture; missing level of development of infrastructure facilities of the agro-food market; insignificant volumes of agricultural insurance carried out with the help of the state.

2 Methodology

The article used methods of analysis and synthesis, generalization of economic processes in the course of implementing the conceptual provisions of the evolutionary approach to the formation of a strategy for sustainable development of the agricultural sector in the context of integrating the interests of EAEU actors in investment activities to achieve the formation of an eco-environment, strengthening information and analytical support for financial instruments in the agricultural sector of the EAEU.

3 Results

Theoretical studies on the development of a mechanism for establishing the financial stability of agricultural producers are considered in the works of such scientists as Nikitin and Shcherbakov (2006), Ushachev et al. (2021), Kotar (2014), Ulibina et al. (2018), Verezubova et al. (2020), Sandu and Belova (2017), Kadomtseva (2019), Kazakevich (2018), the mechanism and trends in the formation of instruments of state regulation and support for the agricultural sector in the conditions of integration are substantiated.

In the Russian Federation, the state program for the development of agricultural production and the regulation of markets for agricultural goods, raw materials and food products plans to allocate funds from the state budget for 2021 in the amount

of 291.2 billion rubles, in 2022—327.3 billion rubles, in 2023—328.9 billion rubles (Government of the Russian Federation, 2012; Sidorenko & Ilyina, 2018).

In accordance with the Federal Law, the state program "On the federal budget for 2021 and for the planning period of 2022 and 2023" has been introduced in Russia; the amount of funds allocated in 2021 is 256.2 billion rubles, in 2022—279.8 billion rubles, in 2023—295.5 billion rubles. As a result, in addition to the reduction in practically allocated funds for the implementation of the state program in 2021–2022, the amount of its allocation of financial resources is reduced in relation to 2020 (Decree of the Government of the Russian Federation, 2012).

In the process of executing the state program in 2020, the level of increase in the production of agricultural products was higher than in other economic sectors.

The agricultural insurance system in Russia with state support instruments was introduced in 1993. Its essence lies in the reimbursement of part of the costs of paying insurance premiums at the expense of the federal and regional budgets.

The study of agricultural insurance trends in Russia showed that for 2020, 2390 crop insurance agreements and perennial plantings were subsidized, which is 1.4 times more than in 2019. The share of subsidies in the paid insurance premium amounted to 49.6%. In 2020, insurance companies insured 5.1 million hectares of crops, or 6.5% (Table 1).

The number of agricultural producers who received subsidies in 2020 amounted to 1665, which is 1.4 times more than in 2019. In total, subsidies were provided in the amount of 1835.2 million rubles (1.3 times more than in 2019), also from the state budget—1523.2 million rubles (Sidorenko & Ilyina, 2018).

In 2017, agricultural producers and individual entrepreneurs who produce agricultural goods could purchase a short-term or investment loan at a rate of less than five percent.

Reimbursement of lost income by the bank comes directly from the state budget according to the key rate of the Central Bank of the Russian Federation (Sidorenko & Ilyina, 2018).

In Russia, there was a positive progress in the size of bank lending to agricultural producers (legal entities and private entrepreneurs), which proves the position of the growing need for domestic agricultural producers of goods to attract additional sources of funds, primarily due to the need for short-term lending during sowing and harvesting (Sidorenko & Ilyina, 2018).

In 2020, the total amount of subsidies provided to authorized banks on interest-free loans, in general in Russia, is 90882.2 million rubles (29.86% more than the amounts provided in 2019), also for concessional short-term lending, this is 20510.8 million rubles (30.21% less than subsidies provided in 2019), for concessional investment lending it is 70371.3 million rubles (73.35% more than subsidies provided in 2019) (Lukashov, 2019; Okorokova et al., 2016; Rusetskiy et al., 2018; Ulibina et al., 2018).

Significant growth demonstrates the agricultural machinery leasing instruments. For example, the volume of deliveries of combines in the first three months of 2021 increased by 155%. Through preferential programs of "Rosagroleasing", 219 combines were purchased for a total amount of over 2 billion rubles, and for the corresponding time period in 2020, this is 86 units in the total amount of 0.6 billion

Table 1 Assessment of trends in the introduction of financial instruments in agricultural insurance in Russia

Indicator	2015	2016	2017	2018	2019	2020	2020 –2019
Cultivated area, mln ha	75.9	76.7	77.5	76.8	77.8	77.9	100.3
Including							
Sown area under insurance contracts	8.3	3.8	1.8	1.3	4.3	5.1	118.6
Share of insured area, %	10.9	5.0	2.3	1.7	5.6	6.5	116.1
Number of entities involved in the development of agricultural insurance	56	40	32	31	42	60	142.9
Number of insurance companies, units	43	21	17	12	14	13	92.9
Number of agricultural producers, units	2751	913	321	310	1219	1665	136.6
Number of subsidized contracts, units	3619	1188	414	416	1685	2390	141.8
Sum insured, million rubles	155.707	114.772	37.664	26.581	112.276	141.613	126.1
Volume of insurance premium, million rubles	8709.7	5657.7	1523.2	1049.1	2828.1	3699.6	130.8
Share of subsidies in paid insurance premium, %	49.1	44.5	49.7	49.9	49.2	49.6	100.8
Loss ratio of agricultural insurance instruments, %	12.3	11.1	11.0	10.1	13.5	44.5	329.8

Source Developed by the authors according to Central Bank of the Russian Federation (2021), Ministry of Agriculture of the Russian Federation (2021)

rubles. Deliveries of tractors also increased by 11%. In the first months of 2021, "Rosagroleasing" delivered 293 tractors for a total amount of 1.4 billion rubles. In 2020, it was possible to increase the supply of agricultural machinery by 35.5% to 9723 units. The amount of investments by the state program "Rosagroleasing" for the purchase of equipment exceeded 38.5 billion rubles. In 2019, the characteristics amounted to 25.5 billion rubles. According to the results of 2021, the state hopes

Table 2 Classification of promising instruments of state regulation and support of the agricultural sector in the context of integration interactions

Instruments	Russia	Kazakhstan	Belarus	Armenia	Kyrgyzstan
Software documentation state support	State programme for the development of agriculture and regulation of markets for agricultural products, raw materials and food for 2013–2025	State program for the development of the agro-industrial complex of the Republic of Kazakhstan for 2017–2021	State program "Agricultural business" for 2021–2025	Programs aimed at the strategy of the main directions ensuring the economic development of the agricultural sector of the Republic of Armenia for 2020–2030	Food Security and Nutrition Program in the Kyrgyz Republic for 2019–2023
Insurance	Federal Law No. 260 "On State Support in the Sphere of Agricultural Insurance and on Amendments to the Federal Law "On the Development of Agriculture" 50%	State support for insurance of agricultural producers 50%	Decree of the President of the Republic of Belarus dated September 7, 2020 No. 336 "On Insurance of the Harvest of Agricultural Crops, Livestock and Poultry in 2021" 95%	Implementation of the agricultural insurance program	Implementation of the agricultural insurance program
Lending	State support for the formation and development of a credit system in the field of agricultural development	Concessional lending	Decree of the President of the Republic of Belarus "On the provision of loans to citizens engaged in personal subsidiary plots"	State support for subsidizing interest rates	Program "Financing of agriculture–8"

(continued)

Table 2 (continued)

Instruments	Russia	Kazakhstan	Belarus	Armenia	Kyrgyzstan
Leasing	Preferential leasing	Subsidized lease rate	State program "Preferential leasing" of the Republic of Belarus"	State support for financial leasing of equipment for the agri-food sector	Project "Financing of leasing of agricultural machinery"

Source Developed by the authors based on Financing of agriculture (2021), Republic of Armenia (2021), Belarus (2021), Government of the Russian Federation (2012), Republic of Kazakhstan (2021)

that the agricultural machinery fleet will increase by 62.8 thousand units (Decree of the Government of the Russian Federation, 2012; Lukashov, 2019).

The state program for the development of the agro-industrial complex of the Republic of Kazakhstan for 2017–2021 is aimed at doubling the size of the gross agricultural output; increasing the export of processed products by two and a half times to 2.7 billion dollars; increasing the amount of attracted credit funds in 2021 by nine times compared to 2017; increasing the inflow of investments in fixed capital into the industry by 3 times (Republic of Kazakhstan, 2021).

For 2016–2020, the share of the agricultural sector in the structure of the GDP of the Republic of Kazakhstan averaged approximately 4.5%. At the same time, the share of the agricultural sector in the structure of the GDP of the Republic of Kazakhstan is decreasing, but not dramatically. In the structure of gross output (services) of agricultural production, 54.5% fell on the crop production sector and 45.5%—on the livestock sector.

The Fund for monetary support of agricultural production is the operator in the field of insurance of the agro-industrial complex. Farmers can insure their assets on the Qoldau.kz Internet resource, using the Agroinsurance information system. In 2021, insurance companies insured 144.8 thousand hectares of crops, of which 121.3 thousand hectares were insured against drought, and 23.5 thousand hectares were insured against excess moisture in the soil. Subsidies in the amount of 176.1 million tenge were paid to agricultural producers on the scale of 112 concluded agreements on index soil moisture insurance. As a result of the occurrence of insured events under 92 concluded contracts, payments amounted to 825 million tenge (Uzun, 2012). In the livestock sector, 39 contracts for insurance of 6,200 heads of cattle, 354 heads of small cattle, 2.1 million heads of birds have been concluded. The provision of insurance premium subsidies for them amounted to 51 million tenge. If in 2016–2018 loans to agricultural companies did not fall below 600 billion tenge, then by the end of June 2020, the loan portfolio in the sector amounted to only 275.3 billion tenge. The main prerequisites for the current situation are the increased requirements of banks for the collateral base of borrowers, the lack of sources of long-term funding in tenge, which are required to allocate funds for projects with a long payback period, as well as higher interest rates on loans.

Despite the worst economic recession in the past twenty-two years in 2020 (GDP of the Republic of Kazakhstan decreased by 2.6%), the portfolio of leasing companies of the Republic of Kazakhstan increased by twenty-nine percent last year and amounted to 393 billion tenge. The portfolio of leasing companies in 2020 amounted to 752 billion tenge and increased by thirty-two percent. If we examine the size of the new business in relation to the current portfolio, then according to the results of 2020, this value was 52% (in 2019–53%). In the portfolio of leasing companies in 2020, agricultural machinery and livestock were in the lead with 39.7% (Lukashov, 2019; Republic of Kazakhstan, 2021).

The Republic of Belarus has introduced the state program "Agricultural Business" for 2021–2025. This program is aimed at increasing the competitiveness of agricultural products, developing export potential, maintaining environmentally friendly agriculture, aimed at strengthening the country's food security (Agricultural Business, 2021).

In the situation of meeting the target levels of agricultural production and a suitable price environment, an increase in exports of food products and agricultural raw materials is expected in 2025 by 21.3% compared to 2020 (up to 7 billion dollars). In addition, it is predicted that the implementation of the measures of the state program will make it possible to ensure profitability in the agricultural sector at the level of more than ten percent by the end of 2025.

The insurance market of the Republic of Belarus is developing through various types of insurance. The insurance market of the Republic of Belarus offers limited types of new insurance services, which leads to a slowdown in the development of the insurance market in Belarus.

After studying the current state of lending to agricultural producers in Belarus, there is a low activity in providing credit to the agricultural sector, which is largely justified by lack of competencies in the field of investment policy, which affects the significant financial indicators of the activities of agricultural producers (Kadomtseva, 2019; Agricultural Business, 2021).

50 companies operate on the leasing services market in the Republic of Belarus. Agricultural producers use leasing tools to modernize production. The prerequisites for this, first of all, are due to the insufficiency of Belarusian producers' own resources.

In the Republic of Armenia, the gross domestic product in the agricultural sector increased by 1.4% compared to 2019. In the field of animal husbandry, an increase of 0.6% was recorded, and in the field of crop production, an increase of 2.3% was recorded.

The scale of sown land plots is 228 thousand hectares, the number of irrigated land plots is 155 thousand (Republic of Armenia, 2021). The agricultural sector insurance program in 2020 was implemented in 6 regions of the Republic of Armenia and included two crops. In 2021, it is planned to increase the number of insured crops to 11 in order to fulfill them in all regions of the Republic of Armenia.

As for state-subsidized agricultural loans, in 2020, compared to the previous year, the number of loans increased by more than 4 times, the size of the loan portfolio doubled.

Among state assistance programs in 2020, significant progress was noted in the leasing program, under which 295 units of agricultural machinery were purchased, and the number of beneficiaries almost doubled (Republic of Armenia, 2021).

In the Republic of Kyrgyzstan, the volume of gross domestic product collected 598 billion soms, which is 8.6% less compared to 2019. At the same time, agricultural production has grown by 1.1%. From 2019 to 2020, farmers and cultivators are facing existing climate challenges.

In Kyrgyzstan, at the initiative of the Ministry of Agriculture, Water Resources and Regional Development, it is planned to adopt a law on insurance in the agricultural sector. In 2020, microfinance organizations issued loans in the amount of 31.1 billion soms, while the number of recipients amounted to about 707 thousand people, the share of microcredits to agricultural producers increased by 2.4 percentage points compared to 2019.

In the Republic of Kyrgyzstan, the state program "Financing of Agriculture—8" has been introduced, it provides for the issuance of loans to farmers and entrepreneurs engaged in agricultural production at reduced rates. 6.2 billion soms were allocated for the state program of preferential loans this year (Financing of Agriculture, 2021).

In 2020, 14 companies that signed more than 560 contracts carried out leasing activities. At the same time, a significant amount (0.5 billion soms, or 39%) of financial leasing agreements, as before, falls on agreements concluded for the purchase of agricultural enginery, machinery and mechanisms (343 units).

4 Discussion

Discussion of the results of the study within the framework of integration interactions shows that in agricultural insurance, according to K.D. Bidzhova, M.E. Kadomtseva, V.G. Korostyleva, O.A. Okorokova, Yu.B. Turaev, several tendencies of their formation are manifested. Market coverage for agricultural insurance is within 40%. Russia has a wide range of tools for agricultural risks. Kazakhstan and Belarus use state compulsory insurance instruments. Armenia applies separate pilot projects in agricultural insurance.

The conducted studies on financial instruments of state support in the agricultural sector of the EAEU prove the possibility of points of contact and interaction, considering the harmonization of the interests of actors in the context of integration and development of the digital technology system.

5 Conclusion

As expected results of the study, an assessment of the potential of agricultural insurance was given, a classification of financial instruments of state support for the agricultural sector within the framework of the EAEU was proposed.

For promising directions for the formation of the agricultural sector in the context of integration interactions, it is necessary to implement the following tasks:

- overcoming crisis segments in the economy, developing seed production and increasing the export of agricultural goods and food products;
- reducing dependence on imports;
- improving the risk management system in the agricultural sector;
- regional development of the potential of the agricultural sector;
- stimulation of innovative financial instruments in the agricultural sector.

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The Design of Learning Results According to International CDIO Standards as a Context for Improving Engineering Education at Agrarian University

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Abstract The need for a meaningful transformation of the professional education of specialists in agroengineering specialization is due to both the increasing demands on the part of employers for the level of training of agricultural engineers, and the intensive development of agricultural technologies and equipment. The authors reveal the features of designing the planned learning outcomes for a qualitative update of the content of modern educational programs of engineering training in an agricultural university based on CDIO standards. The scientific novelty of the research is the development and methodological justification for designing learning outcomes according to international CDIO standards on the example of a separate area of professional training in the agricultural university (35.03.06 "Agroengineering", specialization "Technical systems in agribusiness"). The article describes in detail the design of the results of the training according to international CDIO standards, based on the principles of "result-based" and "practice-oriented" by considering the interaction of the three factors determining the effectiveness of modern agricultural engineering training. These factors include: 1. Federal State Educational Standard of Higher Education (FSES HE); 2. CDIO Syllabus (a content system or a list of employers' requirements for engineering education in terms of attributes (competencies) and 3) the results of a stakeholder survey on the list of significant competencies of an engineering university graduate and their priority. Considering the CDIO approach as one of the leading advanced methods for the development,

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https://doi.org/10.1007/978-981-19-3555-8_16

continuous improvement and evaluation of higher education programs in the field of engineering and technology, the authors propose a further algorithm for creating professional programs by defining the intended outcomes of the training. In the Stavropol State Agrarian University, 12 pilot programs have been developed and are being implemented in a similar way, based on the implementation of the approaches of the Worldwide CDIO Initiative. The result of the design and qualitative updating of educational programs based on CDIO standards will be the formation of a set of professional competencies in demand for graduates of an agricultural university of engineering specialization, allowing them to effectively perform professional tasks and function constructively in the conditions of innovative technological and technical development of agricultural production.

Keywords Higher agricultural education · Engineering education · Planned learning outcomes · CDIO

JEL Code I21 · I23 · I25

1 Introduction

Qualitative changes in the field of higher agricultural education, due to the socio-political and economic realities of Russian society, are aimed at the systematic training of highly qualified personnel capable of carrying out professional activities in a new paradigm of design, production and sale of competitive products. The foregoing fully applies to the training of engineering personnel in an agricultural university, designed to ensure the production potential of modern agriculture.

In the situation of innovative development and technical modernization of agricultural production, the food and processing industry in Russia, the role and requirements for the training of engineers are increasing, because they are the central figure from which the introduction of new equipment and technologies into production, energy, water and the gas supply of the entire agricultural infrastructure and, in general, the efficiency of the vital activity of the markets for agricultural raw materials and food depend. There is an expansion and change in the range of tasks that need to be optimally and quickly solved by future specialists-engineers; they need a much larger set of competencies than just the technical operation of agricultural machinery and equipment.

In this context, the meaningful modernization of engineering agrarian education in higher education seems to be extremely relevant. One of the best ways to achieve this goal, which makes it possible to bring professional education as close as possible to the requirements of real agricultural production, the level of development of modern technologies and the expectations of employers, is the implementation of the CDIO approach in the system of engineering training for the agro-industrial complex. This concept, as an international initiative of the community of engineering teachers, reflects an integrated approach to improving basic engineering education, based on the developed CDIO standards and the list of planned learning outcomes of CDIO.

2 Methodology

An integrated approach has become the leading approach to the study of the problem under discussion, because the methodological novelty of the presented version of the development of educational programs is, first of all, the design of learning outcomes according to international CDIO standards based on the interaction of a set of factors that determine the effectiveness of modern training of engineering personnel in the agricultural sector. Such external factors include: the Federal State Educational Standard for Higher Education, CDIO Syllabus (a content system or a list of employers' requirements for engineering education in terms of attributes (competencies) and the results of a stakeholder survey on the list of significant competencies of an engineering university graduate and their priority. The next part of our work will be devoted to describing the specifics of designing learning outcomes according to international CDIO standards based on the analysis of these factors in the system of agricultural education. During the study, general scientific methods: analysis of scientific literature, questioning, pedagogical modeling were also used.

3 Results

The emergence of new employers' requirements for graduates of agricultural universities of an engineering specialization, as well as the prevailing realities of modern agricultural production, based on the intensive introduction of innovative machinery and equipment, stimulate a constant change in the content of education through the design of new educational programs focused on the formation of a mobile composition of sought-after competencies of future agrarian graduates.

The need for changes in the content of professional training of graduates-engineers of agricultural universities stimulates its design, considering the best international and domestic practices for reforming educational programs in this field. These, first of all, include CDIO standards, focused on the meaningful modernization of engineering education using the principles of "practice-oriented" and "result-based".

Stavropol State Agrarian University has developed and is implementing 12 pilot programs based on the implementation of CDIO approaches (6 undergraduate and 6 master's programs). The total number of students enrolled in CDIO programs in 2021 was 35.9% (of which: 24.8% are undergraduate students, 11.1% are master students).

Let's reveal the specifics of designing the expected learning outcomes according to CDIO standards on the basis of the main professional educational program of higher education, which is taught at the university we are describing in the direction of training 35.03.06 "Agroengineering", specialization "Technical systems in agribusiness".

At the first stage, to design an educational program in the field of study 35.03.06 "Agroengineering", we used the analysis of one of the three key factors considered

when planning learning outcomes. We conducted a survey of 132 stakeholders in order to provide feedback from all parties interested in the quality of the learning process and to continuously improve this educational program. Opinions about the assessment of the importance of graduate competencies based on CDIO Syllabus (a system of engineering education content in terms of attributes (competences) of the following groups of stakeholders: potential employers; teachers of this area of training; students enrolled in this profile (bachelors and masters) were studied by a written survey.

As a result of data processing, a list of the most sought-after competencies of graduates was identified. They are indicated by the most intense color in the table (Table 1).

The results of the choice of graduate competencies by stakeholders showed the dominance of the following attributes of an agroengineering graduate: "in-depth knowledge of the basics of engineering" (unanimously singled out by all respondents as a priority competency); "the ability to manage a team", "understanding the role and responsibility of an engineer"; "systems thinking" and "readiness for the operation of production machines, process equipment and systems". It is the formation of competencies identified by stakeholders as the most important that will be given attention when designing an educational program. At the second stage of designing learning outcomes according to international CDIO standards, the correspondence between the learning outcomes of CDIO Syllabus and the competencies of the Federal State Educational Standard of Higher Education was established. Since CDIO Syllabus includes four semantic blocks of attributes (competences) of a future engineer, as an example of this work, we will present only one block of CDIO Syllabus competencies (Table 2).

Since the specificity of engineering education is due to the complexity of engineering activities according to the CDIO approach (plan–design–production–application), further work related to the design of learning outcomes and updating the engineering training program at an agricultural university included the following actions:

- The learning outcomes obtained were differentiated based on the modules of the professional training program implemented based on the international learning outcomes presented in the CDIO Syllabus.
- General cultural, general professional, professional, professional and applied competencies are interconnected, they were consolidated learning outcomes (LO) and were formed within disciplines (or individual modules). This made it possible for the student, as a future graduate, to organize and perform a certain type of professional activity, including specific labor functions. The achievement of real results of studying the educational program was determined by mastering the group of competencies.
- Based on the requirements of stakeholders and the Federal State Educational Standard, practice-oriented interdisciplinary projects of the full cycle were developed, for the implementation of which the curriculum was transformed. That is, it was

Table 1 The results of the survey of stakeholders on the priority of competencies of agroengineering graduates

Competencies of the future engineer (based on CDIO Syllabus)	Students, GPA	Teachers, GPA	Employers, GPA
1. DISCIPLINARY KNOWLEDGE AND BASIS			
1.1. Exact (formal) sciences	8,1	8,4	8,7
1.2. Engineering (base)	8,8	8,9	8,7
1.3. Engineering (advanced knowledge)	9,2	9,0	9,2
2. PROFESSIONAL COMPETENCES AND PERSONAL QUALITIES			
2.1. Ability to analyze and solve problem situations	8,3	7,6	8,7
2.2. Ability to conduct research	7,6	8,7	8,6
2.3. Systematic mental activity	8,9	8,9	9,4
2.4. Responsibility, ethics and justice	7,9	8,4	8,4
3. INTERPERSONAL SKILLS: TEAM WORK AND COMMUNICATION			
3.1. Organization of effective communication with others	9,0	8,3	8,8
3.2. Ability to manage a team	9,0	8,9	9,0
3.3. Proficiency in communication in a foreign language	7,4	6,9	8,3
4. PLANNING, DESIGN, PRODUCTION AND APPLICATION OF PRODUCTS IN THE CONTEXT OF THE ENTERPRISE AND THE ENVIRONMENT			
4.1. Awareness of the role and responsibility of an engineering worker	8,8	9,3	9,0
4.2. Presence of entrepreneurial initiative	8,6	9,0	7,7
4.3. Ability to analyze technological processes and the results of work performed	8,8	8,8	8,7
4.4. Readiness for the design of equipment and technological processes and production systems	8,6	8,6	8,5
4.5. Ability to organize the production process and comply with safety requirements	8,9	8,9	8,2
4.6. Ability to effectively operate production machines and process equipment	8,9	8,7	9,1
4.7. Ability to organize a team for high-quality completion of production tasks on time	9,1	8,8	8,5
4.8. Ability to organize testing, verification and certification of products and production facilities	8,8	8,5	8,9
4.9. Ability to apply standard algorithms for maintenance, repair and restoration of worn parts of machines and electrical equipment	8,8	8,8	8,7
4.10. Ability to train personnel in the use of devices, technologies and systems	8,4	8,4	8,9
4.11. Ability to complete the life cycle and dispose of products, waste	7,5	8,2	8,5
4.12. Application of effective methods of installation, adjustment of machines and installations	8,6	8,8	9,0
4.13. Ability to innovate	8,3	8,6	9,2
4.14. Manifestation of engineering entrepreneurship skills	8,8	8,2	9,3

Source Compiled by the authors

Table 2 The example of the correlation of competencies in the formulations of CDIO Syllabus and the Federal State Educational Standard of Higher Education in the direction of training 35.03.06 "Agroengineering"

Competences in the formulation of CDIO Syllabus	Competencies in the formulation of the Federal State Educational Standard of Higher Education
4. PLANNING, DESIGN, PRODUCTION AND APPLICATION OF PRODUCTS (SYSTEMS) IN THE CONTEXT OF AN ENTERPRISE, SOCIETY AND THE ENVIRONMENT	
4.1. Social and environmental context	The ability to apply the methods and means of physical culture to ensure a full-fledged social and professional activity (GCC-8); The ability to use first aid techniques, methods of protection in emergency situations (GCC-9); The ability to work in a team, tolerantly perceiving social, ethnic, confessional and cultural differences (GCC -6);
4.2. Entrepreneurial and business context	The ability to use the basics of economic knowledge in various fields of activity (GCC-3); The ability to conduct a valuation of the main production resources and apply elements of economic analysis in practice (PC-14);
4.3. Planning, systems engineering and management	The ability to analyze the technological process and evaluate the results of work (PC-13); Willingness to systematize and summarize information on the formation and use of enterprise resources (PC-15);
4.4. Design	Readiness to participate in the design of technical means and technological processes of production, electrification and automation systems for agricultural facilities (PC-5); The ability to use information technology in the design of machines and the organization of their work (PC-6); Readiness to participate in the design of new equipment and technology (PC-7);
4.5. Production	The ability to organize quality control and process control (GPC-7); The ability to ensure compliance with safety regulations, industrial sanitation, fire safety and labor and environmental protection standards (GPC-8); Readiness to use technical means of automation and automation systems for technological processes (GPC-9);

(continued)

Table 2 (continued)

Competences in the formulation of CDIO Syllabus	Competencies in the formulation of the Federal State Educational Standard of Higher Education
4.6. Application	Readiness for professional operation of machines and technological equipment and electrical installations (PC-8); The ability to use standard technologies for maintenance, repair and restoration of worn parts of machines and electrical equipment (PC-9); The ability to use modern methods of installation, adjustment of machines and installations, maintaining the operating modes of electrified and automated technological processes directly related to biological objects (PC-10);
4.7. Engineering Enterprise Leadership	The ability to organize the work of performers, find and make decisions in the field of organization and standardization of labor (PC-12);

Source Compiled by the authors

implemented considering the modular principle of organization and the project approach.

- The constructed program was implemented through modules built on a logical basis. It was a separate unit of educational material, complete in content and independent, aimed at the formation of a set of the above-mentioned competencies that determine the planned learning outcomes.
- Means for evaluating the results of mastering the educational program, which include: weekly student surveys, ongoing monitoring of progress using a web resource for testing our own design, intermediate certification of students once a month in all disciplines, have been developed.

4 Discussion

Thus, the presented technology of designing learning outcomes according to CDIO international standards is focused on the use of a fundamentally new planning system and meaningful transformation of a qualitative update of the educational program of engineering training in an agricultural university. But there are questions. How do other vocational training institutions use the CDIO concept to design the results of engineering training? What good practices exist in this area and how can they be applied to our realities?

The importance and decisive role of the CDIO approach in modern engineering education is substantiated by a significant number of scientists in their research. For example, Vu, T.L.A., Nguyen, T.T.H [10, p. 600] believe that the CDIO approach is one of the leading advanced methods for developing HE programs implemented by

technical universities (Vu & Nguyen, 2020) [10, p. 602]. The same opinion is shared by Toporkova, O.V. [8, p. 160], who considers the CDIO approach as an innovative basis for the development of educational programs for future engineers. She believes that these changes in engineering curricula are aimed at reducing the gap between the content of engineering educational programs and practice in production, developing competencies for effective work in the field of professional engineering, and, as a result, they contribute to the growth of quality indicators of technical education in modern universities (Toporkova, 2020).

Kohn Rådberg, K., Lundqvist, U., Malmqvist, J., Hagvall Svensson, O. [6, p. 24] argue that through the concept of CDIO as Challenge-Based Learning (CBL), students feel they have gained in-depth skills in problem framing and sustainable development, as well as working across disciplines and with different stakeholders (Kohn Rådberg, Lundqvist, Malmqvist, & Hagvall Svensson, 2020) [6, p. 24]. These same findings are confirmed by the research of a group of scientists who studied the attitudes of students towards the implementation of the "Conceive-Design-Implement-Operate" (CDIO) approach at two universities in Central Vietnam. According to the survey results, all students have a positive attitude towards CDIO, they are more involved and motivated, ready to take more relevant courses in the future (Tran, Pham, Bui, Duong, & Tran, 2020) [9, p. 9819].

Cosgrove T., O'Reilly J., focusing on the need to form interdisciplinary knowledge in engineering competencies in the context of digitalization, reveal the dynamics of changes in the content of professional competencies of modern engineering education from federal state educational standards 3+ to federal state educational standards 3++ and CDIO (Cosgrove & O'Reilly, 2020) [4, p. 43].

The scientific papers also describe various aspects of the experience of using CDIO in the system of meaningful design of vocational education. For example, the CDIO Syllabus Architecture is disclosed as the basis of a structured system for interviewing representatives of the automotive industry and the academic regional community to update the educational goals of undergraduate automotive engineering programs (Bukalova, Dorofeev, & Novikov, 2000) [1, p. 014]; the experience of implementing the Conceive-Design-Implement-Operate (CDIO) idea within the framework of the Russian-Kazakh network training program for specialists for the nuclear industry of Kazakhstan is presented (Geraskin, Krasnoborodko, & Glebov, 2020) [5, p. 243]; a new learning model based on graded iteration and CDIO mode of engineering education is proposed to solve problems that exist in the process of teaching a Java programming course (Yang, 2020) [11, p. 524]; a multi-level interdisciplinary innovative system of teaching engineering disciplines was created on the basis of a practical engineering training center for talented students in China on the principles of learning based on results (OBE) and the concept: "design–implement–act" (CDIO) (Chen, Lin, Ren, & Shen, 2020) [2, p. 169]; an approach that creates conditions for active learning of students, proposed in the CDIO standard, which was tested in two higher educational institutions of Ukraine (State University of Telecommunications and Kiev University named after Boris Grinchenko) and described as part of the Wireless and Mobile Security course program, is disclosed (Buriachok & Sokolov, 2020) [1, p. 622].

In order to introduce students to professional practice as soon as possible, several engineering universities have implemented integrated curricula based on the international CDIO standards of compulsory internship to systematically include on-the-job training as an integrated activity in order to better meet industry requirements and students' competence expectations as future engineers (Rouvrais, Remaud, & Saveuse, 2020) [7, p. 98]. Other scientists, emphasizing that CDIO Standards are an effective means of updating and improving the quality of basic engineering education, went a little further and developed, based on the general idea of the CDIO approach, FCDI Syllabus v1 and FFCD Syllabus v1 for designing master's and postgraduate programs (Chuchalin, 2020) [3, p. 107].

Thus, the CDIO approach is actively used in the development and improvement of educational programs for technical areas of training both in Russia and abroad. Potentially, the CDIO concept can be effectively implemented in any university where engineers are trained.

5 Conclusion

In general, thanks to the introduction of the CDIO concept for designing the learning outcomes of engineering specialists, agricultural universities will have the opportunity to develop competitive practice-oriented educational programs aimed at training highly qualified personnel of a qualitatively new level, with functional readiness to organize effective professional activities in the context of intensive introduction of agricultural machinery and technologies, capable of carrying out stable productive work in a situation of constant increase in their knowledge intensity. The training of specialists with such a set of competencies that are in demand and currently in short supply will provide a solution to an important national economic problem—increasing the productivity of agricultural entities and ensuring the country's food security.

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Environmental Controlling as a Tool for Strategic Management of Sustainable Development of an Agricultural Organization

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Abstract Environmental monitoring is a strategic tool allowing to manage the profit and prestige of the subject, the quality of work and services, to reduce the impact of environmental elements in the course of economic activity. The process of introducing environmental controlling into the activities of economic entities in some cases requires a probabilistic assessment of environmental risks, an analysis of possible losses and damages for an economic entity and a classification of environmental hazards. The economic damage caused by pollution is the cost of pollution. The first part of the cost of pollution is the cost of preventing pollution through pollution control measures. Environmental costs are aimed at neutralizing industrial waste and reducing waste generation through the introduction of low-waste technologies. The second part of the costs of pollution is the direct economic damage from pollution—it consists of the costs of preventing the impact of pollution on recipients and compensating for the consequences of this impact.

Keywords Controlling · Costs · Environmental costs

JEL Codes I21 · I23 · I25

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_17

1 Introduction

Economic damage is quantified by additional costs for facilities operating in a polluted environment, which are mainly the population, agriculture, industry, communications, activities, etc. Economic damage can be considered as a characteristic of the operating conditions of the recipient of pollution and a characteristic of the source of pollution. Economic damage is a management parameter when it is possible to determine the source of its formation and influence it.

To calculate the economic damage, specific indicators per unit of mass pollution are used. Based on the volume and type of pollutants and specific indicators of economic damage, the total cost of each source of pollution is determined.

As a rule, when studying environmental problems associated with the current activities of organizations, they resort to an inventory of waste sources. This type of environmental assessment makes it possible to identify all existing problems, to determine their importance and to identify steps to bring the company up to national or international standards.

2 Methodology

The purpose of the study is to identify the possibilities and limitations of using environmental controlling tools as a strategic management tool for the sustainable development of an agricultural organization.

An inventory of waste generation sources was carried out for each subdivision of the organization separately. On the basis of an inventory, the list of wastes subject to routine accounting; the list of hazardous wastes subject to certification; list of wastes for which generation standards should be defined; the list of wastes for which hazard class and hazard characteristics should be determined; the list of wastes to be collected separately for future use and disposal have been determined for each subdivision and the enterprise as a whole.

3 Results

The methodology for planning the environmental activities of any business entity, including agricultural enterprises, refers to determining the degree of discrepancy between the actual state and state regulation of environmental problems and determining the scope of work, the environment necessary to eliminate the inconsistencies identified, as well as the reasons for their occurrence. The organization of such task encounters certain difficulties, one of which is the identification of environmental aspects through the process of identification (Al-Dousari et al., 2019).

In the previous case, the determination of the environmental aspects of inventory management is an ongoing process that determines the potential post-war environmental impact of our company and its food products. It is important to identify objects and sources of the same type, dangerous properties of substances involved in the technological process. For the purposes of scientific research, the significance of the environmental aspects of waste generation should be assessed (Table 1).

The priority ratio for waste generation from the replacement of lighting fixtures amounted to:

$$K = (K_1 + K_2) * A = (0,0000 + 0,0003) * 5 = 0,0015.$$

The priority ratio for waste generation from the operation of vehicles and special equipment amounted to (Table 2):

$$K = (K_1 + K_2) * A = (0,0011 + 0,00078) * 2,54 = 0,0048.$$

Next, we will evaluate the significance of the environmental aspects of waste generation.

To fulfill the tasks set, we assessed the importance and priority of the environmental aspects of waste production identified at the objects under study according to the formulas:

$$K_1 = \frac{M_i}{\sum M} \tag{1}$$

$$K_3 = \frac{N_i}{\sum N} \tag{2}$$

where, M—the mass of generated waste, t/year;

N—the amount of payment for the negative impact.

According to the results of the inventory of waste sources and the determination of environmental aspects, the main sources (processes) of waste on farms are: replacement of lighting fixtures, livestock and poultry farming, crop production, processing of agricultural products, activity of employees; operation of office equipment; cleaning of premises and territory; repair and welding works; woodworking, cleaning of tanks and local treatment facilities.

Due to the fact that the purpose of this work is to identify the general processes of waste generation for agricultural enterprises in the Stavropol Territory, we assessed the significance of the identified aspects depending on the source and technological process of waste generation (Federal Law of the Russian Federation, 1998).

In ascending order of the priority coefficient, all waste generation processes of agricultural enterprises represent the following series: livestock and poultry farming (K = 0.3969); cleaning of the territory and premises (K = 0.2543); processing of agricultural products (K = 0.108); crop production (K = 0.1042); vital activity of employees (K = 0.0078); operation of vehicles and special equipment (K =

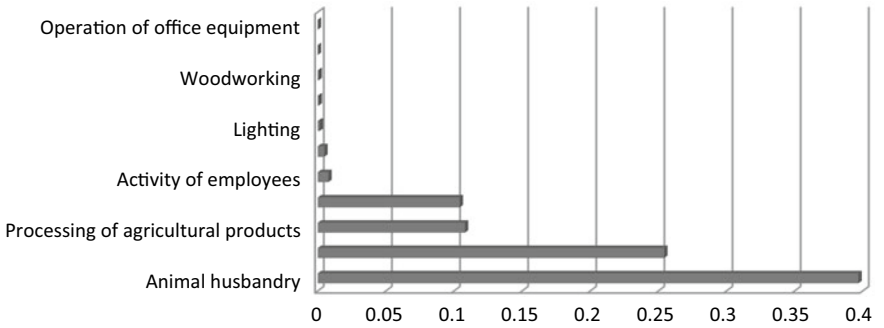

Fig. 1 Values of the coefficient of priority of environmental aspects of waste-generating activities of agricultural enterprises. *Source* Compiled by the authors

0.0048); replacement of lighting fixtures (K = 0.0015); repair and welding works (K = 0.0007); woodworking (K = 0.0006); operation of office equipment (K = 0); cleaning of tanks and local treatment facilities (K = 0). The ranked series is clearly shown in Fig. 1.

The obtained results make it possible to decide on the choice of the main environmental aspects of an agricultural enterprise, for which environmental protection measures should be a priority in order to reduce the negative impact on the environment.

Traditionally, there are three main types of environmental impacts:

– social impact;
– economic effect;
– environmental impact.

Social consequences that often do not require costs and improved health at the same time are accompanied by a number of economic results, for example, an increase in the amount of lost benefits as a result of a decrease in labor productivity due to the morbidity of workers in a polluted environment; overtime pay for workers who were replaced by sick people; a decrease in operational activities due to the poor health of an employee; loss of food, sick days, etc. (Voronkova et al., 2019).

It seems to us that it is necessary to consider the improvement of the company's reputation as a new result of the implementation of the environmental control system. At this stage, the company's environmental and social policy also affects the company's image.

Impact on the environment, reduction of payments, reduction of environmental damage (harm to people), reduction of consumption, reduction of resource losses; the economic effect is to increase income by changing prices, costs and increasing production; social pressure is to reduce the incidence and mortality of the population. We believe that this is not enough to motivate the company's management (Méndez-Bautista et al., 2009).

The impact of agricultural waste on the environment is manifested throughout the entire technological chain: from waste generation, through the collection, use, transfer to third parties, disposal, storage and disposal of waste. This impact leads to negative consequences in economic terms, which leads to economic losses in the national economy. This is justified by the fact that waste, substances and energy are finally removed from the production process.

The management of the reduction and restoration of environmental damage should be based on an assessment of the natural impact of environmental pollution during waste treatment, as well as on specific environmental and economic instruments. The improvement of tools and the development of new elements should help to improve the quality of waste management (Massicotte et al., 2020).

It can be concluded that the introduction of environmental controlling procedures is important, because the economic effect is achieved through waste disposal and modernization of production processes.

At present, everyone understands that any product can be a source of environmental pollution and depletion of natural resources. It becomes more and more obvious that it is necessary to search for new, acceptable in Russian conditions, ways and approaches to minimizing the anthropogenic impact. The development of eco-efficient business and environmental management has become a major pathway in the developed world (Albekov et al., 2018).

4 Conclusion

The following points, which can have a positive impact on their competitiveness, deserve attention in the activities of enterprises.

Companies working on the problem of interaction with the environment can improve their sustainability. As a result, you will have more opportunities to reduce the costs (payments) for your waste, especially the negative impact on the environment.

Enterprises confirm the quality of their products in accordance with the rules of environmental protection, and also strengthen their position in the market in changing conditions (competitive potential of the organization).

The introduction of an environmental control system will open up new opportunities for you, such as financial savings, efficient production and commercial potential.

At the same time, effective and systematically applied environmental management creates an atmosphere of trust in relations with all those involved in its activities, whether it be government or society. On the contrary, if environmental management methods are not used, the risk arises from inadequate or insufficient control of the impact of production activities on the environment.

Thus, environmental control as an agricultural enterprise management system provides a search for viable and economically viable opportunities for applying the environmental and social needs of the enterprise.

Table 1 Register of environmental aspects of waste generation from the replacement of lighting fixtures of the agricultural production cooperative collective farm "Kazminsky"

Environmental aspect	Criteria for assessing the significance of the environmental aspect				
	Waste generation mass		Payment for waste disposal		Environmental hazard index
	M, t/year	K1	N, rub./year	K3	A
1	2	3	4	5	6
Fluorescent mercury lamps used and defective	0,2225	0,0000	1712,9	0,0003	5

Source Compiled by the authors

The implementation of environmental controls provides companies with a tool that allows them to more efficiently and effectively manage the various sources and factors affecting the environment, as well as to adapt their activities to various environmental requirements, thus ensuring sustainability.

Table 2 Register of environmental aspects of waste generation from the operation of vehicles and special equipment

Environmental aspect	Criteria for assessing the significance of the environmental aspect				
	Waste generation mass		Payment for waste disposal		Environmental hazard index
	M, t/year	K1	N, rub./year	K3	A
1	2	3	4	5	6
Waste battery sulfuric acid	0,6982	0,0000	2302,7	0,0004	4
Waste lead batteries, not dismantled	1,3614	0,0000	2995,4	0,0005	3
Waste engine oils	12,889	0,0027	28,358,2	0,0049	3
Transmission oils	5,0646	0,0011	11,143,2	0,0019	3
Industrial oils	0,0110	0,0000	24,2	0,0000	3
Hydraulic oils	2,5722	0,0005	5659,4	0,0010	3
Cotton waste	0,3445	0,0000	378,8	0,0001	2
Waste tires	5,263	0,0011	5787,5	0,0010	2
Waste air filters	0,213	0,0000	234,2	0,0000	2
Waste oil filters	0,601	0,0001	660,9	0,0001	2
Ferrous scrap	33,602	0,0071	252,4	0,0002	1
Copper alloy scrap	8,7856	0,0019	311,2	0,0000	1
Brake pads	1,0844	0,0002	31,2	0,0000	1
Total:	72,489	X	58,139,3	X	X
Average value:	X	0,0011	X	0,00,078	2,54

Source Compiled by the authors

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Psychosemantic Analysis of the Economic Consciousness of Students of Agricultural University Under the Conditions of Digitalization of the Economy

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Abstract The relevance of the research topic is determined by the need of society in specialists with high economic efficiency, capable of planning strategies for self-realization in the economy in current conditions of development of the labor market and digitalization of the economy. The paper aims to study the economic consciousness of students of economic specialties of Stavropol State Agrarian University. The study used the method of experimental psychosemantics (semantic differential) and the method of multivariate statistics (factor analysis). The authors identified the basic constructs of the ordinary consciousness of students in the field of economics, through which they perceive the current economic reality. A comparative analysis of the results of the experimental and psychological study of economic consciousness of first- and fourth-year students is presented. It was revealed that first-year students perceive economic reality through constructs such as "strength-weakness" and "leadership," and fourth-year students—through the constructs "morality" and "responsibility-irresponsibility." In the ordinary consciousness of first-year students, the image of a businessman, a financially literate person, a financially secure person, and a contemporary student is perceived as strong and possessing leadership qualities. In the ordinary consciousness of fourth-year students, the image of a businessman, a financially literate person, a financially secure person, and a contemporary student is perceived as moral and responsible. The use of the possibilities provided by the method of private semantic differential to study the economic consciousness

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_18

of students of a higher agricultural education institution is fundamentally new for the conducted experimental study.

Keywords Personality of a student · Economic consciousness of an individual · Experimental psychosemantics · Private role semantic differential

JEL codes I25 · Z1

1 Introduction

The economic consciousness of the individual is formed under the influence of specific socio-economic changes occurring in society. It is an urgent problem of psychological research, which is reflected in the scientific works of today's scientists, including the works of Vospitannik and Koroleva (2019), Kuriukin (2018), Ostanova (2021), and Yakushev (2015).

The studies by Lenchuk and Vlaskin (2018), Mihnevich (2019), Ognivtsev (2019), Osovin (2018), and Polozhikhina (2018) note that the vector of economic development is currently shifting towards the expansion of digital space and global digitalization of the world economy, which generates new models of personal economic awareness.

In Russian psychology, there are different approaches to understanding the structure of the economic consciousness of the individual. Drobysheva (2017), Saifudinova et al. (2021) define economic consciousness as a psychological regulator of economic behavior, which is formed in the process of secondary socialization of an individual.

Savchenko, Ageeva and Rodzikovskaya (2018) consider social attitudes, perceptions, subjective evaluations, opinions, and personal sense of economic phenomena as the main elements of personal economic consciousness.

Korokoshko (2009), Malyukova (2016), Golubeva and Istratova (2013) identify the following components in the structure of economic consciousness: images and ideas in the economic sphere, economic thinking, norms in the economy, and motives of economic activity.

Zhuravleva (2020) and Khashenko (2015) distinguish a person's self-perception as an active participant of activity in the economy, the ideas about financial and competitive relations determining an individual's economic behavior in the labor market, etc. as structural units of economic consciousness.

Gochiyaev and Kitova (2011), Popova (2017) note that the period of education in higher educational institutions is an important period for economic socialization of students, within which personal economic consciousness is formed.

Consequently, there arises a need to study the economic consciousness of students to predict their behavior in the current socio-economic reality and identify ways to optimize the educational process in the field of economics.

The works of Kutyrev (2015), Bazarova (2010), Gasanova and Daudova (2017) provide a rationale for applying the method of experimental psychosemantics to study the economic consciousness of an individual.

Nevertheless, we revealed the insufficient degree of study of economic consciousness using the method of experimental psychosemantics in future specialists in agriculture, which determines the relevance of this research.

2 Materials and Methods

The research used the method of experimental psychosemantics (semantic differential) and the method of multivariate statistics (factor analysis).

The private role semantic differential is a combination of scaling procedures and the method of controlled associations. It is an adequate way to study the economic consciousness of an individual.

The development of the private role semantic differential consisted of selecting descriptor scales: qualitative characteristics of personality represented, for the most part, by adjectives or phrases (e.g., practical, appreciates money, rational, etc.).

Psychological diagnostics of the subjects by means of the private semantic role differential consisted in their evaluation of the proposed roles on a seven-point scale:

1. Myself;
2. Me in ten years from now;
3. Contemporary person;
4. Businessman;
5. Financially literate person;
6. Temporarily unemployed person;
7. Financially insecure person;
8. Financially secure person;
9. Person who does not resemble me;
10. Contemporary student;
11. Contemporary woman student.

The processing of the scales by the examinees was performed by summing up the individual protocols through the construction of a 50×11 group matrix with further processing of the results by multivariate statistics—factor analysis. The result of factor analysis was the identification of factor structures with correspondingly significant factor loadings. When interpreting the results, the content of the scales and their placement in the semantic space were evaluated.

3 Results

Experimental psychological research was conducted at the Stavropol State Agrarian University. A total of 326 students were tested using the private role semantic differential to examine the economic consciousness of students (the first group—186 first-year students; the second group—140 fourth-year students), studying in the following areas:

- Business Informatics;
- Economics;
- Management;
- State and municipal administration;
- Commerce;
- Finance and credit;
- Economic security.

At the first stage of the research, we organized psychological diagnostics of first- and fourth-year students. The diagnostics were carried out by presenting them with a private role semantic differential.

The second stage of the research involved processing and interpreting the results of the psychological diagnosis of the subjects by factor analysis. After processing the primary results of psychological diagnostics of a sample of first-year students using factor analysis, we identified only five factors (Fig. 1).

Two bipolar factors were identified with a significant factor load. The variance level of the first factor was 29.85%, the variance of the second factor was 17.15%.

The first factor (29.85%) was formed by the following scales: strong, brave, smart, modern, appreciate money, creative, and with a negative sign—weak, stupid, wasteful, outdated, and impractical.

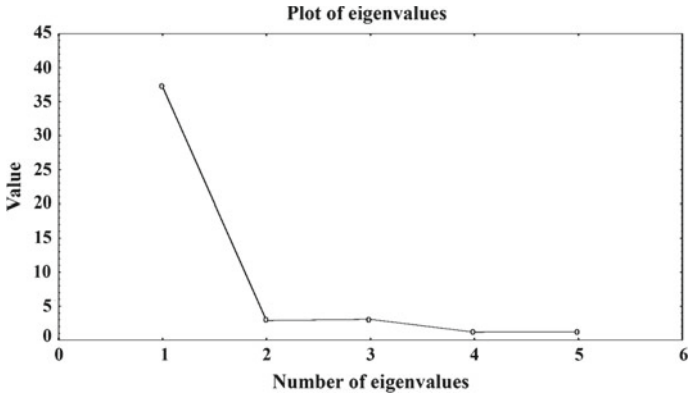

Fig. 1 Results of processing of primary data of psychological diagnostics of a sample of first-year students using factor analysis. *Source* Compiled by the authors

Table 1 Distribution of the factor load of role positions in a sample of first-year students

Role positions	Factor load				
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Myself	0.28193	0.291883	−0.33154	1.517952	−0.47187
Financially insecure person	−1.56036	−0.66355	−0.6213	0.60093	1.601591
Financially secure person	0.68501	1.791168	−0.20686	0.234778	−1.38557
Me in ten years from now	0.58114	0.8892	−0.19449	−0.42379	0.198117
Contemporary person	−0.56361	−0.465765	−0.41459	−1.22547	−1.16491
Financially literate person	1.09753	0.759618	−0.51354	−1.66809	0.963778
Businessman	0.972496	1.68661	0.468217	1.009385	−0.61457
Temporarily unemployed person	−0.713222	−0.599231	1.664895	−0.00801	0.903712
Contemporary student	0.605419	0.600231	1.65457	0.136115	0.478875
Contemporary woman student	−0.69515	−0.319794	−1.905	0.494505	0.476147
Person who does not resemble me	−1.05501	−1.881168	−0.20686	0.234778	−1.38557

Source Compiled by the authors

Role positions in the semantic space were distributed in importance as follows: on the positive pole—a financially literate person (1.09), a businessman (0.97), a financially secure person (0.68), a contemporary student (0.60), me in ten years (0.58), and myself (0.28).

The following role positions were registered at the opposite pole of the semantic space—a financially insecure person (−1.56), a person who does not resemble me (−1.05), a temporarily unemployed person (−0.71), a contemporary woman student (−0.69), and a contemporary person (−0.56) (Table 1).

When interpreting the results of factor analysis, we relied on the qualitative and quantitative composition of the scales included in a particular factor.

Based on the content of the scales, we called the first factor "Strength-Weakness."

The role positions of a financially literate person and a businessman by factor load in this factor are opposed to such role positions as a financially insecure person and a temporarily unemployed person.

First-year students perceive financially literate persons and business people as strong, brave, smart, modern, money appreciating, and creative people.

On the contrary, the role position of a financially insecure, temporarily unemployed person is perceived and described by first-year students as weak, stupid, wasteful, outdated, and impractical.

The analysis of students' self-identification with the proposed role positions showed that the role positions "myself" and "me in ten years" in the common mind of first-year students positively correlate with the role positions financially literate person and businessman. These role positions are described as strong, brave, smart, modern, and creative people who appreciate money.

The analysis also revealed the opposition of the role position of the contemporary student, located at the pole of strength, and the role position of the contemporary woman student, which is close to the image of the temporarily unemployed, located at the pole of weakness.

Analysis of the second bipolar factor (17.15%) in the sample of first-year students showed that it included the following scales distributed in the semantic space:

- The positive pole—leader, pragmatic, strong, able to predict events, smart, kind, and persistent;
- The negative pole—dependent, coward, unprincipled, unable to predict events, and not inclined to risk.

Consequently, we can interpret this factor as "leadership."

The result of factor analysis was the following distribution of role positions in the semantic space: the positive pole includes the following roles in descending order—a financially secure person (1.79), a businessman (1.68), me in ten years (0.88), a financially literate person (0.75), a contemporary student (0.60), and myself (0.29). In the common mind of first-year students, these role positions are represented by such characteristics as a leader, pragmatic, strong, able to predict events, smart, kind, and persistent.

The images of a person who does not resemble me (−1.88), a financially insecure person (−0.66), a temporarily unemployed person (−0.59), a contemporary person (−0.46), and a contemporary woman student (−0.31) were distributed at the opposite pole of the semantic space. They are presented in the ordinary consciousness of students as dependent, coward, unprincipled, unable to predict events, and risk-averse.

It was found that first-year students in the present time (myself) and in the future (me in ten years) positively correlate themselves with images of a financially secure person, a businessman; they consider themselves to have leadership qualities and be pragmatic, strong, able to predict events, smart, kind, and persistent.

After processing the primary results of psychological diagnostics of a sample of fourth-year students by factor analysis, we identified only four factors (Fig. 2).

We detected two bipolar factors with significant factor loading. The variance level of the first factor was 19.11%, and that of the second factor was 11.23%.

The first factor (19.11%) was formed by scales such as moral, rule-abiding, kind, sympathetic, able to predict events, disciplined, intelligent, practical, and emotional. The opposite pole includes scales such as indifferent, immoral, evil, unable to predict events, wasteful, adventurous, stupid, and weak.

Based on the content of the scales, we called this factor "morality."

It was found that the following role positions are opposed in the everyday consciousness of fourth-year students, which is reflected in the semantic space: a financially secure person (1.22), a contemporary student (1.05), a financially literate person (0.94), a businessman (0.80), myself (0.66), me in ten years (0.65), a financially illiterate person (-0.88), a person who does not resemble me (-0.61), a contemporary person (-0.44), and a temporarily unemployed person (-0.33) (Table 2).

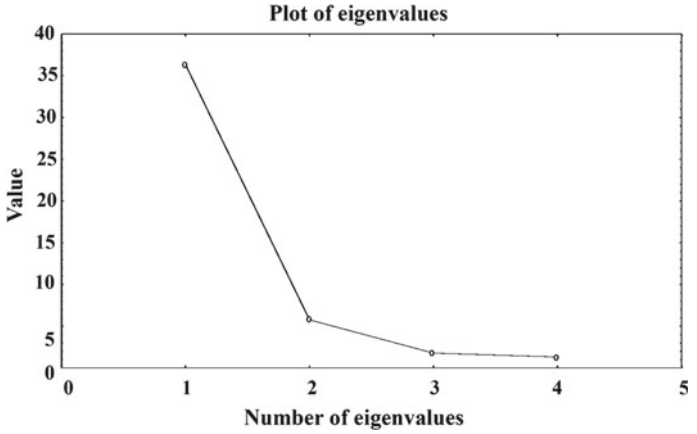

Fig. 2 Results of processing of primary data of psychological diagnostics of a sample of fourth-year students by factor analysis. *Source* Compiled by the authors

Table 2 Distribution of the factor load of role positions in a sample of fourth-year students

Role positions	Factor load				
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Myself	0.66193	0.431883	−0.33154	1.517952	−0.47187
Financially insecure person	−0.88036	−1.28355	−0.6213	0.60093	1.601591
Financially secure person	1.22501	0.811168	−0.20686	0.234778	−1.38557
Me in ten years from now	0.65114	0.6692	−0.19449	−0.42379	0.198117
Contemporary person	−0.44361	−0.795765	−0.41459	−1.22547	−1.16491
Financially literate person	0.94753	0.999618	−0.51354	−1.66809	0.963778
Businessman	0.802496	1.75661	0.468217	1.009385	−0.61457
Temporarily unemployed person	−0.333222	−0.279231	1.664895	−0.00801	0.903712
Contemporary student	1.055419	0.700231	1.65457	0.136115	0.478875
Contemporary woman student	−1.28515	−0.619794	−1.905	0.494505	0.476147
Person who does not resemble me	−0.61501	−0.811168	−0.20686	0.234778	−1.38557

Source Compiled by the authors

In the common consciousness of fourth-year students, the role positions of a financially literate person are located at the same pole with the role position of the contemporary student. Students perceive these images as moral, rule-abiding, kind, responsive, able to predict events, disciplined, intelligent, practical, and emotional.

On the contrary, indifferent, immoral, evil, unable to predict events, wasteful, adventurous, stupid, and weak are role positions of a financially insecure, contemporary, and temporarily unemployed person.

The analysis of the identification of fourth-year students with the role positions showed that the image of the present self (myself) and the future self (me in ten years) correlate with the role positions located at the pole of morality, together with the images of a financially secure and a financially literate person.

The analysis of the second bipolar factor (11.23%) in the sample of fourth-year students showed that it included and distributed the following scales in the semantic space: responsible, disciplined, obliging, rules-compliant, moral, predictive, decisive, rational, active, and intelligent. The opposite pole includes scales such as irresponsible, undisciplined, does not follow the rules, irrational, spontaneous, and unable to predict events.

Role positions in the semantic space were distributed in the following way:

- The positive pole—a businessman (1.75), a financially literate person (0.99), a financially secure person (0.81), a contemporary student (0.70), me in ten years (0.66), and myself (0.43).
- The negative pole—a financially insecure person (−1.28), a person who does not resemble me (−0.81), a contemporary person (−0.79), a contemporary woman student (−0.61), and a temporarily unemployed person (−0.27).

Based on the content of the scales, we called this factor "responsibility-irresponsibility."

Such role positions as a businessman, a financially literate person, and a financially secure person are located at the same pole with the image of a contemporary student, which is presented in the ordinary consciousness of students as responsible, disciplined, obligatory, complying with the rules, moral, able to predict events, decisive, rational, active, and intelligent.

A financially insecure person, a contemporary person, and a temporarily unemployed person are associated with the image of the contemporary woman student and are characterized as irresponsible, undisciplined, not following the rules, irrational, spontaneous, and unable to predict events.

The image of self in the present (myself) and in the future (myself in ten years) is perceived by fourth-year students as responsible, financially literate, and financially secure people.

4 Conclusion

The socio-economic life of society in the era of digitalization of the economy generates new models of the economic consciousness of the individual. Therefore, there arises the need for psychological science to expand research on this phenomenon.

This research aimed to study the economic consciousness of the students of economic specialties of the first and fourth years of the Stavropol State Agrarian University.

A comparative analysis of the results obtained using the method of experimental psychosemantics and factor analysis confirmed the hypothesis that the economic consciousness of students in different courses has its own specifics.

Psychosemantic analysis of economic consciousness of students showed the peculiarities of the identification of first- and fourth-year students with the role positions. It also allowed us to identify the basic constructs of the economic consciousness of students, through which they perceive the economic reality. These constructs include "strength-weakness," "leadership" (in first-year students), "Morality," and "Responsibility—irresponsibility" (in fourth-year students).

In the ordinary economic consciousness of first-year students, the images of a businessman, a financially literate person, and a financially secure person are perceived as strong and possessing leadership qualities. In the ordinary consciousness of fourth-year students, it is perceived as moral and responsible.

First-year students perceive themselves in the present and future as strong, capable of leadership, financially literate, and financially secure. Fourth-year students perceive themselves as moral, responsible, financially literate, and financially secure.

The research novelty was an attempt to study economic consciousness using the method of experimental psychosemantics in first- and fourth-year students of the agricultural university. In a practical sense, the research results can be used to predict the economic behavior of students in today's digitalized economy.

Further research of economic consciousness of students using the method of experimental psychosemantics can be carried out with the allocation of additional socio-psychological features of personality: gender, age, professional, typological, etc.

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Food Security Challenges to Agriculture and a Promising Response to Them in AgroTech

Tatiana N. Litvinova

Abstract The purpose of this research is to identify the food security challenges to agriculture and the benefits of responding to these challenges in AgroTech. It has been carried out using the trend analysis method, correlation analysis method, and logical (qualitative) analysis method. It has been concluded that food security poses several serious challenges to agriculture, and the capabilities to respond to them in low-tech agribusiness are limited. The identified challenges include the loss of agricultural land; rural population decline; the need to increase the share of agriculture in the value-added structure of GDP; the need to increase the food production index; a decrease in the proportion of arable land. It has been substantiated that AgroTech provides a promising response to all these challenges, to which end author's recommendations are made. The contribution of the paper to the literature is that it has clarified the cause-and-effect relations of the provision of food security and identified the role and significance of agriculture in achieving it. The scientific and practical value of results obtained is that they have opened up a new wide field for future research on the provision of food security through the use of AgroTech.

Keywords Food security · SDG2 · Agriculture · Agrotech

JEL Codes F52 · Q18 · M15 · O13 · O14 · O18

1 Introduction

Food security (implementation of SDG 2) is the common concern of the entire humankind, although it has different manifestations in countries around the world (Liu et al., 2022). Some developing countries are most acutely affected by food deficit, while others are most acutely affected by high risks of farming: both natural (reduction of yields) and marketing (difficulty in exports, instability of earnings due to the inability to influence international food prices) (Deléglise et al., 2022). The

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_19

problem at issue is manifested in developed countries in the form of the dependence on food imports and inflation in the food markets (Zongo et al., 2022).

Despite its different manifestations, the solution to the food security problem is general and it belongs to the sphere of agriculture (Ogbolumani & Nwulu, 2022; Rahman et al., 2022). AgroTech has become a new vector of agricultural development in the context of the Fourth Industrial Revolution. It is a digital segment of agricultural markets where disruptive technologies are actively used: AI, Big Data and IoT. Education and progress of AgroTech are affected in an effort to increase the competitive advantage of farming. The agricultural market leaders introduce disruptive technologies to retain their dominant position, while their competitors do the same to enter these markets and achieve a dominant position in them.

In this regard, AgroTech has been most studied from the perspective of its benefits to entrepreneurship and economic growth, while its impact on food security is understudied. The working hypothesis of this research is that AgroTech contributes to achieving food security since it provides a promising response to the food security challenges to agriculture. This research is concerned with testing the advanced hypothesis and is aimed at identifying the food security challenges to agriculture and the benefits of responding to these challenges in AgroTech.

2 Literature Review

The pivotal role of agriculture in the provision of food security has been pointed out in the works of Neme et al. (2021), Sadati et al. (2021), Soice and Johnston (2021), Yankovskaya (2021). The benefits of AgroTech to agriculture have been described in detail in the studies by Astafeva et al. (2020), Erdoğan (2022), Ho (2021), Jellason et al. (2021), Osipov and Ronˇcevi´c (2021), Popkova et al. (2022), Sergi and Popkova (2022), Spanaki et al. (2021).

The review and the content analysis of available literature bring us to the conclusion that it lacks a comprehensive concept of food security challenges to agriculture, and that AgroTech contributes to providing a response to these challenges, which is a research gap that is filled in this paper.

3 Materials and Method

The advanced hypothesis and the purpose in view have determined the logic and structure of this research that is aimed at studying and consistently solving two problems. The first problem: to identify food security challenges to agriculture. The trend analysis method is used for this end to determine an increase in food security and its potential drivers of agriculture in 2015–2021 (changes in the relevant indicators are shown in Table 1).

Table 1 Changes in food security and its potential drivers of agriculture in 2015–2021

Country	Potential drivers of agriculture											
	Food security index (score 0–100)		Arable land (% of land area)		Food production index (2014–2016 = 100)		Agriculture, forestry, and fishing, value added (% of GDP)		Rural population (% of the total population)		Agricultural land (% of land area)	
	2015	2021	2015	2018	2015	2018	2015	2020	2015	2020	2015	2018
Austria	80.9	84.0	16.31	16.08	97.36	101.86	1.13	1.10	42.29	41.25	32.94	32.15
Chile	79.9	81.3	1.77	1.63	101.40	101.63	3.64	3.86	12.64	12.27	21.23	21.11
China	81.9	80.9	12.69	12.68	100.85	103.09	8.39	7.65	44.50	38.57	56.09	56.08
Costa Rica	78.5	79.9	4.96	4.95	98.29	108.84	4.75	4.67	23.14	19.23	34.81	34.91
Finland	77.7	79.1	7.38	7.38	99.52	92.81	2.25	2.45	14.78	14.48	7.48	7.48
Ireland	65.6	74.8	6.58	6.55	100.69	110.06	0.90	0.93	37.46	36.35	64.31	65.55
Netherlands	70.4	73.6	30.95	30.32	100.01	86.90	1.72	1.58	9.83	7.76	54.83	54.11
Qatar	72.5	73.6	1.33	1.22	109.43	112.64	0.16	0.34	1.06	0.77	5.90	5.83
Russian Federation	68.1	73.2	7.43	7.43	100.13	104.50	3.87	3.70	25.95	25.25	13.16	13.16
United States	72.1	71.3	17.12	17.24	96.97	105.95	1.04	1.04	18.33	17.34	44.24	44.36

Source Compiled by the author based on the materials of The Economist Impact (2022), World Bank (2022)

Table 1 presents the data for 2015, as well as the most current data that have been calculated to date. In addition, the correlation analysis method is used to determine the relationship between food security and its potential drivers. The second problem: to identify a promising response to the food security challenges to agriculture in AgroTech. The logical (qualitative) analysis method is used for this end.

4 Results

Within the scope of the first problem of this research, Table 2 (based on the data from Table 1) is used for the calculation of an increase in food security and its potential drivers of agriculture compared to 2015.

As can be seen in the data in Table 2, arithmetical averages of the increase of each indicator under study were calculated, and the correlation between food security and its potential drivers of agriculture has been determined (Fig. 1).

Results in Fig. 1 are indicative of the following food security challenges to agriculture and promising response to them in AgroTech. The first challenge: the loss of agricultural land (by 0.31% compared to 2015), the change in which by 41.98% determines the change in food security. The promising response to this challenge in AgroTech consists in the expansion of environmentally smart technologies that enable high-producing agriculture even in those territories which have been considered unsuitable for this purpose before. In this regard, the criteria for the definition of agricultural land which will include land that was allocated for agricultural use

Table 2 An increase in food security and its potential drivers of agriculture compared to 2015, %

Country	Food security index	Arable land	Food production index	Value added in agriculture	Rural population	Agricultural land
Austria	3.83	−1.41	4.62	−2.64	−2.44	−2.41
Chile	1.75	−7.62	0.23	6.15	−2.90	−0.58
China	−1.22	−0.09	2.22	−8.75	−13.32	−0.02
Costa Rica	1.78	−0.39	10.73	−1.59	−16.89	0.28
Finland	1.80	0.07	−6.74	8.74	−1.98	−0.06
Ireland	14.02	−0.44	9.31	3.71	−2.98	1.94
Netherlands	4.55	−2.02	−13.11	−8.24	−20.99	−1.30
Qatar	1.52	−8.50	2.93	109.99	−27.49	−1.18
Russian Federation	7.49	0.00	4.36	−4.46	−2.71	0.00
United States	−1.11	0.70	9.26	−100.00	−5.42	0.27

Source Calculated and compiled by the author

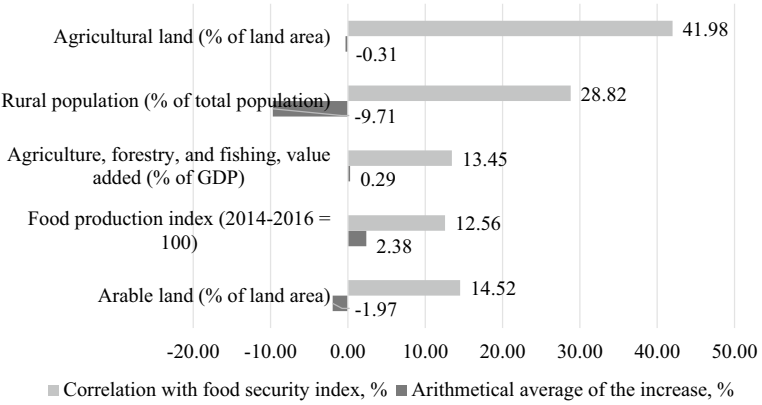

Fig. 1 Average increase in food security and its potential drivers of agriculture, and their correlation, % *Source* Calculated and compiled by the author

regardless of its suitability rather than land that is well suited for it, have been reviewed.

The second challenge: rural population decline (by 9.71% compared to 2015), the change in which by 28.82% determines the change in food security. The promising response to this challenge in AgroTech consists in the creation of smart rural areas, providing knowledge-intensive employment and high living standards. This will make it possible to launch the de-urbanization trend since living in smart rural areas will not only be equally prestigious, economically promising and convenient compared to living in cities, but also more environmentally friendly.

The third challenge: the need to increase the share of agriculture in the value-added structure of GDP (it has increased by 0.29% only compared to 2015), while its change by 13.45% determines the change in food security. The promising response to this challenge in AgroTech consists in the possibility of a sharp increase in productivity in agriculture through the implementation of advanced automation means.

The fourth challenge: the need to increase the food production index (it has increased by 2,38% only compared to 2015), while its change by 12.56% determines the change in food security. The main complexity is that along with the increase in food production, it is necessary to guarantee its high quality. The promising response to this challenge in AgroTech consists in improving the food quality as a result of its improved monitoring with the use of computer vision in the practice of public management, as well as blockchain for the monitoring of value-added chains in agribusiness in the practice of public management.

The fifth challenge: decrease in the proportion of arable land (by 1.97% compared to 2015), the change in which by 14.52% determines the change in food security. The promising response to this challenge in AgroTech consists in the possibility of the creation of vertical farms as an alternative or addition to horizontal farms. As a result, it will enable crop production on arable land of a far smaller area, while agricultural productiveness will remain the same or even be increased.

5 Conclusion

In conclusion of this research, inference should be drawn that food security poses several serious challenges to agriculture, and the capabilities to respond to them in low-tech agribusiness are limited. The identified challenges include the loss of agricultural land; rural population decline; the need to increase the share of agriculture in the value-added structure of GDP; the need to increase the food production index; a decrease in the proportion of arable land.

AgroTech provides a promising response to all these challenges, to which end author's recommendations are made. The contribution of the paper to the literature is that it has clarified the cause-and-effect relations of the provision of food security and identified the role and significance of agriculture in achieving it. The scientific and practical value of results obtained is that they have opened up a new wide field for future research on the provision of food security through the use of AgroTech.

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Applied Recommendations and Frameworks of the Development of AgroTech

Neural Networks and Artificial Intelligence in Stockbreeding and Forecasting Dairy Cattle Productivity

Svetlana A. Braginets, Olga V. Galanina, and Vadim S. Grachev

Abstract Stockbreeding in the dairy farm is carried out by highly qualified specialists. To increase milk yields and milk fat content, during the selection of pairs, the specialists consider the information about their ancestors—mothers, mothers of mothers, and mothers of fathers. Based on the analysis of information (milk yield and fat content) on the first lactation of the mother, the mother of the mother, and the mother of the father, the authors create a neural network prediction of the daughter's milk yield and fat content. The experiment used a forward propagation neural network with two hidden layers of 18 and 10 neurons each. Various productive properties of ancestral combinations of the mother, the mother of the mother, and the mother of the father were used as input streams. The training sample consisted of 200 animals with information on their milk yields and fat content in the first lactation. The test sample included 20 animals. The test results show that the neural network is quite good at predicting productivity results. However, the analyzed information is insufficient to increase the prediction accuracy even with the increased number of ancestors. Presumably, it is necessary to consider not only the milk yield and fat content of the ancestors but also the quantity and quality of feed, the state of the veterinary service, the second and subsequent lactations, and other zootechnical information. It is also necessary to conduct additional experiments with the neural network architecture to increase the volume of the training sample.

Keywords Neural network · Multilayer perceptron · Stockbreeding · Artificial intelligence · Dairy farming · Pairing

JEL Codes C10 · C45 · Q16

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_20

1 Introduction

Today is the era of the digital revolution. Artificial Intelligence (AI) and neural networks are gradually embracing larger areas of human life. Agro-industrial complex (AIC), including crop and livestock farming, is no exception. The digitalization of the AIC is associated primarily with the Internet of Things (IoT) with embedded smart modules.

AI is much more powerful than the intelligence of the best specialist, and it is cheaper for the producers of agricultural products. It allows replacing the labor of many expensive specialists with an artificial brain that can be controlled even by a novice. Primarily, the use of AI improves the quality of management decision-making.

How valid is the statement that the work of a breeding specialist in dairy cattle breeding can be replaced by a robot, a neural network, or AI? Evidently, for AI to be successfully trained and implemented in production, it is necessary to process large amounts of information accumulated by humankind (Big Data). Only in this case can the neural network learn (with or without a teacher) and produce new knowledge, patterns, and classifications.

The analysis of Russian and foreign secondary scientific literature has shown that the most commonly used digital technologies are the systems of computer vision, the IoT, and neural network models.

The analyzed literature describes interesting applications of neural networks in dairy cattle breeding, including the following:

- Forecast of cow behavior in a complex environment (Cairo et al., 2020);
- Forecast of milk yields based on deep learning (Craninx et al., 2008);
- Early detection of sexual libido based on the analysis of cow behavior (Chang & Heinemann, 2019);
- Forecast of calving based on behavior analysis (Frasco et al., 2020);
- Forecast of milk yield of first heifers on the first test day (Grzesiak et al., 2010);
- Solution of the problem of classification of healthy and sick buffalo mastitis (Panchal et al., 2016);
- Forecast of the incidence of mastitis in cows (Sefeedpari et al., 2013);
- Identification of cows with insemination problems (Wallhäußer et al., 2013).

The works of Russian scientists led by V. M. Kuznetsov are devoted to a new BLCIP method for predicting milk productivity of dairy cows (Titova & Kuznetsov, 2005). However, the authors believe that the proposed method is complicated and labor-intensive, requires high mathematical training of a breeding specialist, and is unsuitable for a layperson.

Digitalization implies the simplification of various spheres of human intellectual activity. AI can provide a powerful impetus to the intensification of all spheres. The authors of the research have already tested the possibility of forecasting crop yields using neural networks of direct propagation (Galanina, 2020). Therefore, there is

a logical idea to test the possibilities of neural network programming in predicting milk yields and the fat content fraction of milk in dairy cows.

Analyzing the best world experience, the authors found no works devoted to intellectual analysis of breeding work, selection of pairs, and analysis of the ancestral influence on productive qualities of dairy cows. Are AI and neural networks capable of analyzing information about ancestors with a certain degree of probability to predict the productive qualities of descendants?

The present research aims to investigate this issue.

So far, infrastructure and technical capacities (cloud and fog services, high-speed broadband Internet, etc.) are lacking for Big Data analysis and large-scale use of AI.

2 Materials and Methods

The productive qualities of daughters (D) are known to be influenced by the productive qualities of mothers (M), mothers of fathers (MO), and mothers of mothers (MM). It is established that properties such as productivity (U), milk fat content (G), and milk protein content (B) are inherited. Highly qualified specialists carry out a selection of pairs and stock breeding to increase the productivity of milk and fat content of milk in herds. Entire breeding plants and research organizations are engaged in this work. Specialists effectively apply methods of correlation and regression analysis, tools for testing statistical hypotheses, and analysis of variance.

The correlation matrix presented in Fig. 1 shows the complexity of pairing decisions.

The authors analyzed a sample in a dairy herd consisting of 200 black-and-white breeds, which had been eliminated from the herd during the last three years. The analysis considered the information on productivity (U), fat content (G), and protein content (B) only for the first lactation of the daughter (UD, GD, and BD), the mother (UM, GM, and BM), the mother of the father (UMO, GMO, and BMO), and the mother of the mother (UMM, GMM, and BMM). It turned out that in the studied sample, a positive correlation is observed between the following features:

- The milk yield of the daughter and the milk yield of the mother (0.11);
- The milk yield of the daughter and the milk yield of the mother of the mother (0.24);
- The fat content of the daughter's milk and the fat content of the mother's milk (0.18);
- The fat content of the daughter's milk and the protein content of the mother's milk (0.16).

A negative correlation is observed between the following indicators:

- The daughter's milk yield and the protein content of the mother's milk (−0.10);
- The daughter's milk yield and the protein content in milk of the mother of the father (−0.10);

	U_M	U_{MM}	U_{MO}	G_M	G_{MM}	G_{MO}	B_M	B_{MM}	B_{MO}	U_D	G_D	B_D
U_M	1											
U_{MM}	0.10	1										
U_{MO}	0.08	-0.05	1									
G_M	-0.14	-0.10	-0.12	1								
G_{MM}	0.00	-0.01	0.05	0.17	1							
G_{MO}	-0.06	0.06	-0.08	0.04	-0.06	1						
B_M	-0.10	0.07	-0.13	0.37	0.00	0.11	1					
B_{MM}	-0.14	-0.28	0.11	0.13	0.32	-0.01	-0.04	1				
B_{MO}	-0.16	0.01	-0.30	-0.01	-0.05	0.38	0.01	-0.02	1			
U_D	0.11	0.24	-0.03	-0.04	-0.07	-0.08	-0.09	-0.10	-0.10	1		
G_D	-0.02	-0.11	0.00	0.18	-0.09	-.02	0.16	-0.08	0.01	-0.03	1	
B_D	-0.04	-0.09	-0.06	0.01	0.08	0.14	0.06	-0.13	-0.07	-0.11	0.16	1

Fig. 1 Correlation matrix. *Source* Compiled by the authors

- The fat content of the daughter's milk and the milk yield of the mother of the mother (−0.11).

In the presence of such complex influences and unobservable patterns, it is recommended to use neural networks of direct propagation for forecasting because they consider comprehensive complex relationships between the signs, which are difficult to predict by regression and other tools.

The multilayer perceptron implements black-box modeling. For the researcher, it does not matter what neural connections are involved in modeling the phenomenon. The researcher specifies only a set of input parameters, a set of output parameters, a neural network architecture, a training sample, and a test sample to evaluate the quality of simulation (Fig. 2).

In predicting the daughter's milk yield and fat content of milk, Model 1 uses the information on the milk yield and fat content of milk of the mother and the mother of the father. Model 2 uses the information on the milk yield and fat content of milk of the mother and the mother of the mother. Model 3 uses the information on the milk yield and fat content of milk of the mother, the mother of the father, and the mother of the mother.

The authors chose a multilayer perceptron with two hidden layers of 18 and 10 neurons each since this architecture is sufficient for modeling in most cases.

The output layer always contained two neurons—the daughter's predicted milk yield (U_D) and the fatness of her milk (G_D).

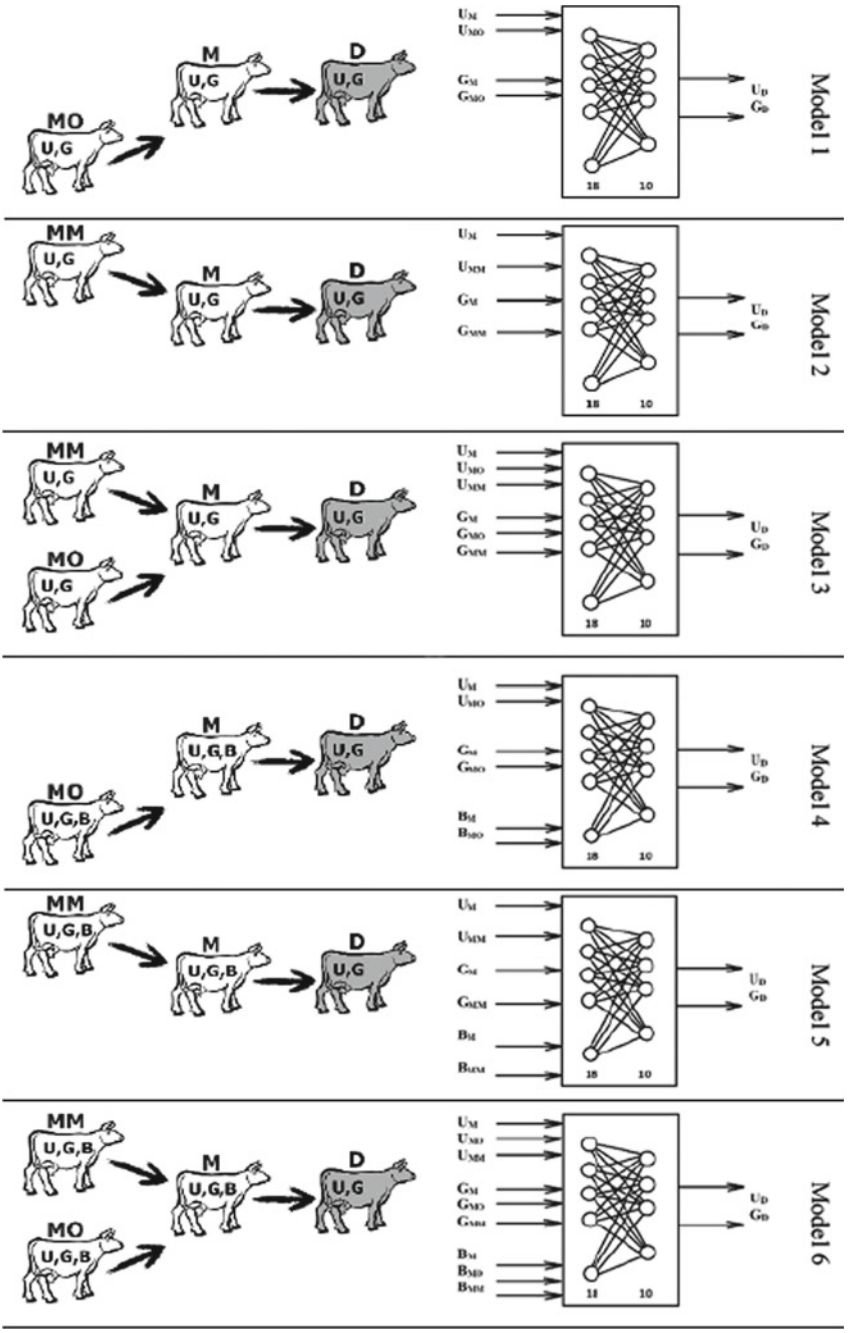

Fig. 2 Scheme of the data selection for the experiment and the corresponding neural network prediction model. *Source* Compiled by the authors

In the Models 1, 2, and 3, various ancestral combinations were selected without regard to the protein content of milk. For example, in Model 1, the input layer of neurons involved milk yield of the mother (U_M), the fat content of the milk of the mother (G_M), milk yield of the mother of the father (U_{MO}), and fat content of the milk of the mother of the father (G_{MO}).

In Model 2, the input layer of neurons involved milk yields of the mother (U_M), the fat content of the milk of the mother (G_M), milk yield of the mother of the mother (U_{MM}), and fat content of the milk of the mother of the mother (G_{MM}).

In Model 3, the input layer of neurons involved milk yields of the mother (U_M), the fat content of the milk of the mother (G_M), milk yield of the mother of the mother (U_{MM}), the fat content of the milk of the mother of the mother (G_{MM}), milk yield of the mother of the father (U_{MO}), and fat content of the milk of the mother of the father (G_{MO}).

Previously, it was substantiated that increasing the number of inputs influencing factors into the neural network improved the prediction quality (Galanina & Zolotaryova, 2020). Thus, the authors decided to test whether adding information about the protein content of the milk of the mother (B_M), the mother of the mother (B_{MM}), and the mother of the father (B_{MO}) to the input layer of the neuron improves the prediction quality.

This led to the second cycle of experiments with the training and testing of neural networks.

As in the previous series, the authors selected a perceptron of the same architecture and the same number of layers of neurons in the output layer (U_D and G_D). The only difference was the addition of the information on the protein content; that is, the input layer of neurons consisted of the following:

- Model 4—U_M, G_M, B_M, U_{MO}, G_{MO}, and B_{MO};
- Model 5—U_M, G_M, B_M, U_{MM}, G_{MM}, and B_{MM};
- Model 6—U_M, G_M, B_M, U_{MO}, G_{MO}, B_{MO}, U_{MM}, G_{MM}, and B_{MM}.

In predicting the daughter's milk yield and fat content of milk, Model 4 uses the information on the milk yield, the fat content of milk, and protein content of milk of the mother and the mother of the father. Model 5 uses the information on the milk yield, the fat content of milk, and the protein content of milk of the mother and the mother of the mother. Model 6 uses the information on the milk yield, the fat content of milk, and protein content of milk of the mother, the mother of the mother, and the mother of the father (first lactation).

3 Results

The results of neural network forecasting were summarized in Tables 1 and 2.

It turned out that all neural networks gave reliable results for milk yield and fat content. The simulation result was compared with the actual result. For this purpose, the coefficient of variation between the predicted and actual values was calculated.

Table 1 Actual and forecasted results for Models 1, 2, and 3

Number of test specimen	Actual		Forecast for Model 1		Forecast for Model 2		Forecast for Model 3	
	U_D, kg	G_D, %	U_D, kg	G_D, %	U_D, kg	G_D, %	U_D, kg	G_D, %
1	9683	3.76	7573	3.72	9018	3.81	751	3.78
2	9749	3.72	9282	3.80	9327	3.82	9404	3.80
…	…	…	…	…	…	…	…	…
20	8983	3.92	8275	3.84	9406	3.83	9758	4.09
Average value	9324	3.82	8985	3.80	8948	3.82	9264	3.84
Standard deviation	791	0.05	748	0.05	503	0.07	850	0.11
Variation coefficient, %	–	–	11.4	1.5	11.7	2.2	11.2	3.0

Source Compiled by the authors

Table 2 Actual and forecasted results for Models 4, 5, and 6

Number of test specimen	Actual		Forecast for Model 4		Forecast for Model 5		Forecast for Model 6	
	U_D, kg	G_D, %	U_D, kg	G_D, %	U_D, kg	G_D, %	U_D, kg	G_D, %
1	9683	3.76	7373	3.83	9206	3.91	11,186	3.69
2	9749	3.72	9978	3.78	9474	3.79	9400	3.81
…	…	…	…	…	…	…	…	…
20	8983	3.92	8773	3.84	9473	3.80	9033	3.93
Average value	9324	3.82	9400	3.81	9017	3.79	9423	3.82
Standard deviation	791	0.05	869	0.06	923	0.06	914	0.08
Variation coefficient, %	–	–	11.4	1.9	13.9	2.2	11.5	1.7

Source Compiled by the authors

The coefficient of variation in all six models was about 11–13% for milk yield and about 1–3% for fat content. It should be noted that when the number of input neurons increased, the quality of prediction improved insignificantly.

4 Discussion

Although the neural network predicted a reliable result of the productive and fat-content qualities of cows by analyzing the complex relationships between these indicators of their ancestors, it is necessary to consider the following conclusions.

A sample of only 200 animals was used to train the neural network; the test sample was only 20 animals. Cross-validation was not used to assess the quality of the simulation.

The architecture of the neural network was a two-layer perceptron with 18 and 10 neurons in each. The neural network of such architecture does not always provide qualitative results. The model's behavior with other neural network architecture is not analyzed in this work, and its quality is not evaluated.

The work does not show that increasing the number of ancestors under study increases the quality of the prediction and that increasing the number of input parameters in some cases can harm the quality of the simulation.

5 Conclusion

Based on the above, the following conclusions can be made:

- Neural network prediction showed that AI and neural networks could successfully replace breeding specialists and pair selection specialists in dairy cattle breeding;
- Neural networks predict the productive qualities of cows quite qualitatively by analyzing the yields of mild and fat content in milk of the maternal and paternal ancestors;
- To increase the accuracy of the prediction, it is necessary to increase the size of the training sample and conduct cross-validation;
- To compare simulation results, it is necessary to analyze neural networks of different architectures;
- Increasing the number of input parameters does not always improve the quality of the prediction provided by the neural network.

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Blockchain Information System—A Tool for Digitalization of the Agricultural Sector

Violeta I. Blazheva and Oksana G. Karataeva

Abstract The paper aims to examine blockchain technology in terms of its ability to consolidate information in a way that is transparent to consumers, primarily in the agricultural sector. In terms of methods, the development focuses on analyzing the increasing need to trace the supply chain from producers to end-users. The main results of the introduction of blockchain technology boil down to achieving transparency in the origin and quality of the products (goods) produced to avoid food fraud in the supply chain. The authors express their opinion that the advancement of blockchain technology will not replace the systems currently in use but will complement and modernize them. This is possible only with the participation of the government. The research novelty lies in the fact that the considered technology is a new business model creating the opportunity to reach new customers. From this perspective, producers and processors need to contribute information isolated as an array of data known as a blockchain. The blockchain platform is a new information system in the agricultural sector. Digitalization of the economy, including the agricultural sector, is possible with the direct participation of the government, namely through the creation of broadband Internet infrastructure, weather stations, the consolidation of data from farms, and the participation of specialists.

Keywords Blockchain · Technology · Digitalization of the economy · Agricultural sector · Europe 2020

JEL Code O32

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_21

1 Introduction

A blockchain platform is an advanced technology for collecting data of different nature and its consumption by various economic entities. It is perceived as the basis for collecting, processing, analyzing, and administering information.

The introduction of blockchain technology in the Digital Farming and Rural Strategy of the Republic of Bulgaria allows tracking crops in real-time.

The successful implementation of this technology requires the funding of 9–12 million leva. Combining the diversity of registers and data sets (State Farming Fund, Bulgarian Food Safety Agency—BABPP, etc.) in a blockchain platform will preserve unified operational information (EIP-AGRI, 2018).

The use of decentrally entered data (including data from agricultural producers, food processors, and traders) will become possible in real-time by all consumers. We can define the following stages:

- The first stage—combining existing data registers;
- The second stage—an overlay of data sets allowing analyzing and improving the prediction models;
- The third stage—the delineation of blockchain technology as a method of secure information exchange and the identification of its capabilities to fully automate data processing.

The above provides an opportunity to reveal several important aspects in the field of blockchain technology as a tool for the digitalization of the economy and the agricultural sector.

The research aims to find out the possibility of creating a blockchain platform as an advanced information system for the needs of the agricultural sector. The research goals are as follows:

- To study the regulatory framework of digitalization of the economy, including the agricultural sector;
- To present the main characteristics of blockchain technology recognized as a decentralized information system;
- To study the indicators of analysis of the discussed issues;
- To establish the limitations of the analysis and indicate areas for future research.

During the research, the authors studied European and national documents in search of real statistical information on the achievements of digitalization in the economy in the agricultural sector, which allowed the authors to analyze and comment on the present situation.

2 Methodology

At the European level, the main policy documents are summarized in "Europe 2020: A strategy for smart, sustainable, and inclusive growth" with the leading initiative presented in it—the Digital Europe Program, the so-called Digital Agenda.

National documents of strategic importance in the field of information and communication technologies (ICT) are as follows:

- National Broadband Infrastructure Plan for Next Generation Access (2012–2020);
- Updated Electronic Communications Policy of the Republic of Bulgaria (2015–2018);
- Updated Strategy for the Development of Electronic Government in Bulgaria (2019–2025);
- Innovative strategy for smart specialization of the Republic of Bulgaria (2014–2020);
- Concept of Digital Transformation of Bulgarian Industry;
- Strategy for Digitalization of Agriculture and Rural Areas of the Republic of Bulgaria (Ministry of Agriculture, Food and Forestry of the Republic of Bulgaria, 2019), etc.

These documents serve as a prerequisite for implementing the envisaged activities in the long term (i.e., the results have a future-oriented nature).

To measure the level of digital transformation in Europe, an index measuring the development of member states in the field of digital technology, namely the Digital Economy and Society Index (DESI), was introduced in 2014. Considered as a composite index, it is an aggregate of certain significant factors. The index combines five general factors:

1. Connectivity;
2. Human capital;
3. Use of Internet services;
4. Integration of digital technologies;
5. Digital public services.

The first, second, and fourth factors are identified as the most important for the digitalization of European industry.

At the European level, the advantages of advanced technology are not fully exploited (Ilieva, 2019). It should be noted that 99% of businesses are defined as small and medium-sized. That is why digitalization is required.

3 Results

A prerequisite for introducing digitalization in the economy, including the agricultural sector, is a well-developed broadband access system.

There has been an increase in broadband access in recent years. Nevertheless, more action is needed in funding, surveillance, etc.

To measure the implementation of digitalization in the agricultural sector in support of the long-term goals outlined in the strategic plans, the following indicators are specified:

- The indicator "digitalization of agriculture" is proposed to define modernization for meeting the cross-cutting objective of the European Union and encourage knowledge acquisition, innovation, and digitalization of the agricultural sector and rural areas (European Parliament, 2020). It is defined as the share of farms that use assistance to implement precision farming technologies under the Common Agricultural Policy of the European Union.
- Concerning the specific community objectives of employment, economic growth, social inclusion, and local development in rural areas, the performance indicator (applicable only to activities supported by the European Agricultural Policy)—"digitalization of the economy in rural areas" (European Parliament, 2020)—is measured by the population in assisted rural areas under the "Smart Villages" strategy.
- To modernize the agricultural sector through "providing agricultural producers access to research, training, and exchange of knowledge and services," to transfer knowledge and innovation, and to define the digitalization of agriculture, it is common to use the share of farms applying assistance for precision farming technology and smart agriculture in the context of European agricultural policy of the total number that can reduce the use of raw materials and improve sustainability and environmental performance.
- In relation to the digitalization of the rural economy, an indicator is also proposed (European Parliament, 2020), which examines the proportion of the rural population covered by the digitalization of agriculture and the proportion of rural areas covered by the "Smart Village" strategy.

There are significant differences within the European farming community regarding the adoption of digital technology. Regional development, implementation sectors, farm size, etc., can be cited as determining factors. Their combination is crucial to creating a profile of the "digital economy" (Ilieva, 2019) and the informational needs of the economy.

In terms of return on investment, each farm needs an adapted use case and a digitalization plan or strategy.

4 Conclusion

We can make the following conclusions based on the research:

1. The research results are more of a theoretical nature because they are related to the long-term implementation of the goals.

2. There is a need for publicly available information that allows us to analyze the state of digitalization of the economy, including the agricultural sector.
3. The practical significance of the research is related to the study and formation of the conceptual apparatus and, in particular, the statement that the blockchain is a decentralized information system.
4. Prospective designs are useful for research in this area, provided that there are sufficient data and realistically established indicators.

In conclusion, we can summarize that a blockchain platform is a tool and source of new knowledge for agricultural producers in presenting and popularizing the developments of scientific organizations.

Access to an integrated workflow management system will create an opportunity for transparency of production activities and up-to-date information about the condition of the plants and animals being grown.

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Effects of Replacing Cereal Concentrates with Grain-Free Feeds on Growth and Development of Weaned Foals

Olga G. Sharaskina, Tatyana N. Golovina, Marina T. Moroz, Vyacheslav I. Samorukov, and Alexander N. Stepanov

Abstract High-carbohydrate grain (HG) concentrates are used in the diets of weanling foals to meet their high energy requirements for growth and development, but they often cause growth that is too rapid and increase the risk of developmental orthopedic disease such as osteochondritis dissecans and can predispose gastric ulceration. This study evaluated the effect of a grain-free diet on the growth and development of Orlov trotter foals and compared to foals receiving a HG diet. Ten foals (6 colts, 4 fillies) after weaning at 6 months were divided into two equal groups. All foals received mixed grass hay (crude protein (CP)—8.5%, crude fiber (CF)—21.3%) ad libitum and balancer supplement for foals. The HG group (HG) received a standard ration with mixed feed based on micronized grain (ME—11.6 MJ/kg, CP—15%, CF—7.5%, starch + sugar (S)—47%); grain-free group (GF) received pellets consisting of alfa-alfa meal, beet pulp, sunflower meal, flaxseed meal, wheat bran. (ME—11.7 MJ/kg, CP—15%, CF—21%, S—6%). The amount of feed was rationed individually, considering the needs of foals in accordance with the "Norms and rations for feeding farm animals" (Beguchev in Anim Husb 3:14–20, 1965). Foals were measured and blood samples were collected prior to receiving the treatment diets and after 90 days. The indicators of relative growth were considered. Data were analyzed using STATISTICA v.10 (StatSoft.ru). Following the 90-day period, there were no significant differences in any of the measurements or in the relative increase in each parameter ($P > 0.05$). In both groups, blood indicators were within the normal range, but GF had significantly higher ($P < 0.05$) content of erythrocytes, hemoglobin and magnesium and significantly lower ($P < 0.05$) cholesterol than in HG. Weanlings grow and develop normally on grain-free diet and did not differ

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https://doi.org/10.1007/978-981-19-3555-8_22

in growth rates from the foals on a grain diet. The high levels of erythrocytes and hemoglobin in GF is possibly caused by alfa-alfa meal and the higher magnesium content in the components of grain-free feed (2.7 g/kg) than in grain mix (0.4 g/kg). Such a diet with a minimum amount of starch and sugar and high in CF can be used to raise Orlov trotter foals.

Keywords Feeding horses · Diet · Weaning foals · Grain concentrates · Grain-free feed

JEL Code Q16

1 Introduction

The first year of a foal's life is the most responsible due to the most intensive growth and development of the body, its plasticity and susceptibility to changes under the influence of feeding and maintenance conditions. In order to maximize the potential of a foal's growth at this age, it is essential to provide it with sufficient available energy and nutrients. This becomes especially relevant after weaning a foal from its mother.

Grain concentrates are traditionally used in the diets of weaned foals to meet their high energy requirements for growth and development. To ensure high growth intensity on the one hand and to reduce the cost of raising foals on the other hand, horse breeders most often use traditional cereal grains (oats, barley) with a high content of starch and sugar (Mack et al., 2014; Subbotin, 2013). Moreover, if we consider the recommendations on feeding young horses and trotting breeds, the norms for feeding grain concentrates are very high. So, for 6–12-month-old foals, it is proposed to introduce 3–6 kg of oats into the diet (Kalashnikova et al., 2003; Subbotin, 2013). On the one hand, this amount of grain concentrates really covers the energy needs of the foal for intensive growth, but, on the other hand, it does not fully provide the necessary nutrients for normal development (unless additional high-protein foods are introduced), and also creates additional load on the functions of the gastrointestinal tract and can affect the formation of orthopedic pathologies. Modern studies show that exceeding the maximum recommended intake of starch (1–1.5 g/kg body weight per feeding) (Dicks et al., 2014; Kabe et al., 2016) can lead to the development of gastric ulcers (Verveurt et al., 2009). According to published data, the incidence of ulcers in foals ranges from 22 to 51% (Elfenbein & Sanchez, 2012; Murray, 1989). Another problem that has been associated with the use of large amounts of grain concentrates is developmental orthopedic disease (DOD) (Lepeule et al., 2009) and insulin resistance, which can also increase the likelihood of developing osteochondritis dissecans (OCD) in foals (Treiber et al., 2005). Despite the fact that OCD is a complex multifactorial disease, many studies (Jeffcott & Henson, 1998; Pagan et al., 2001; Secombe & Lester, 2012; Weeren, 2006) support overfeeding concentrates high in unstructured carbohydrates as a predisposing factor.

Replacing grain concentrates with alternative sources of energy and nutrients for foals is a necessary condition for the prevention of the above problems. But the suggestion to replace grains with high-fiber feeds is often met with distrust by horse breeders, as feeding recommendations (Kalashnikova et al., 2003) suggest that excess fiber reduces the energy and nutritional value of the diet, which can lead to reduced growth rate, as well as to the formation of "hay belly" (Kabe et al., 2016; Newbold & Dougal, 2017).

The purpose of our work was to study the possibility of replacing grain concentrates with grain-free feeds with a high fiber content when growing Oryol trotter weaned foals and assessing the effect of a grain-free diet on the growth and development of foals in comparison with grain-based diets.

2 Methodology

The material for the study was weaned foals of the Oryol trotter breed. Ten foals (6 colts, 4 fillies) after weaning at the age of 6 months were divided into two groups of analogues based on origin, sex, measurements and date of birth.

Foals after weaning at the age of 6 months were kept in individual stalls 3 × 3 m. All daylight hours the foals were in levadas, in groups divided by sex. Feeding with concentrated feed was carried out individually, in stalls, in the morning and in the evening. Access to hay was unlimited both in the stalls and on the walking grounds. To account for the amount of hay eaten by foals, the following method was used: the amount of hay eaten in the stall by each foal was considered daily. To do this, each portion of hay placed in the stall was weighed, and once a day (in the morning) all uneaten hay was taken out of the bedding and feeder and weighed. The difference between the obtained values was used to determine the amount of hay eaten by each foal individually in the stall.

To determine the amount of hay eaten on walking grounds (in levadas), the total amount of hay (kg) allocated to the group of foals and remaining at the end of the day was considered daily. The resulting difference was divided by the total number of foals in the group.

Watering was carried out from buckets, three times a day.

All foals received cereal-forb hay (crude protein (CP)—8.5%, crude fiber (CF)—21.3%), a balancing supplement for foals. The control group (HG) received a standard diet with mixed feed based on micronized grains (barley, corn, wheat, peas, soybeans). The experimental group (GF) received pellets consisting of alfalfa grass meal, beet pulp, sunflower meal, linseed meal, wheat bran as a concentrated feed.

The amount of feed was normalized considering the individual needs of foals and their age and live weight, using the recommended feeding rates for foals of trotting breeds 6–12 months old (Kalashnikova et al., 2003), adjusted to NRC recommendations (2007).

To assess the indicators of growth and development, at the beginning of the accounting period, when the foal reaches the age of 6 months (D1) and 90 days

later (D90) after the start, measurements were taken: height at the withers, oblique body length, chest circumference, metacarpal circumference, chest width in front, chest depth, width in points of hip.

Physique indexes were calculated: bony, format, stubble, massiveness, pelvic-thoracic. The indicators of absolute and relative growth were determined.

Before and at the end of the accounting period, blood samples were taken for biochemical and general clinical analysis. The analysis was carried out on a Mindray BC-2800 Vet hematology analyzer. The concentrations of total protein (TP), albumin (Alb), globulins (Glb), urea (URE), urea nitrogen (BUN), creatinine (CRE), total bilirubin (TBIL), alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), amylase (AML), glucose (Glu), cholesterol (CHOL), calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), sodium (Na), chlorides (Cl^-), iron (Fe), triglycerides (TG), lipase (LPS), lactate dehydrogenase (LDH), gamma-glutamyl transferase (GGT), creatine kinase (CK) were determined.

Statistical data processing was carried out using the program Statistica v.10 (Statsoft.ru). The group mean (Mean) and standard deviation (SD) were determined. Group data were compared using Student's t-test. Differences were considered significant at $P \leq 0.05$. Blood test data were processed using the Mann–Whitney U test.

3 Results

The foals in the study were born between April and May and were at least 6 months old at the start of the study. The groups were formed according to the principle of analogues, not only considering the sex and origin of the foals, but also considering the age, because in this age period the foals have a high growth rate, and a difference of 1 month in age can significantly affect the results.

All foals before weaning, under mothers, received top dressing from a mixture of micronized grain. Thus, the foals from the HG group continued to receive their usual food, and the GF foals were accustomed to eating the new food within 14 days. By the end of the second week, all foals in the GF group were eating a full daily portion of feed well.

During the study, foals in both groups ate food well. The content of dry matter in the diet averaged 3% of live weight. The amount of concentrates in both groups was 1.1–1.3 kg/head/day, hay was given at the rate of 7–8 kg/head/day. Actual hay consumption averaged 7 ± 0.3 kg/head/day. The content of metabolic energy in the diets of foals in both groups was 27–28 MJ/100 kgBW, crude protein—360–375 g/100 kgBW. The content of calcium and phosphorus in the diets of both GF (Ca—29 g/100 kgBW, P—12 g/100 kgBW) and HG (Ca—28 g/100 kgBW, P—13 g) were almost the same. But in the HG group, the amount of starch and sugar supplied daily with feed was 540–550 g higher than in the GF.

For the entire period of the study, there were no differences in the state of fatness or activity of foals both within groups and between groups. Growth indicators were

monitored by seven measurements. The foals were measured according to the breed standard for age in both groups. There were no significant differences in measurements, in relative and absolute growth between the groups (Figs. 1 and 2). Also, no significant differences were found in the indices of the index score.

The results of clinical and biochemical blood tests at the beginning of the accounting period did not reveal significant differences in foals in different groups. At the end of the period, a significant ($p < 0.02$) increase in the concentration of

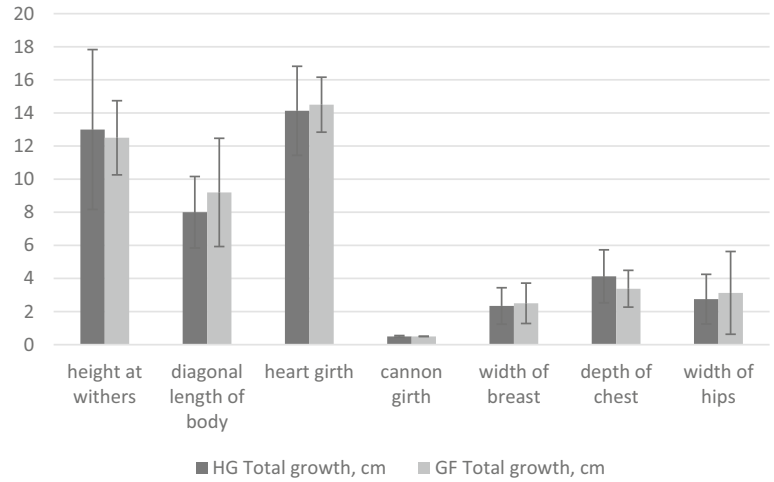

Fig. 1 Comparative assessment of HG and GF groups of weaned foals by the absolute increase in measurements. *Source* Compiled by the authors

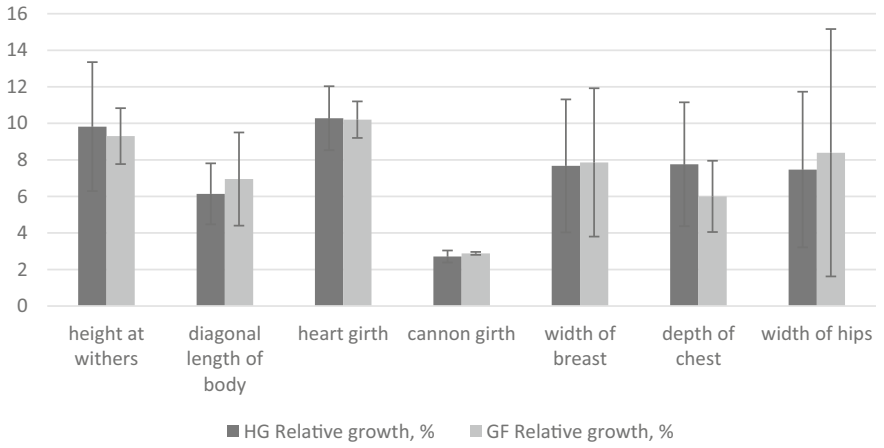

Fig. 2 Comparative assessment of HG and GF groups of weaned foals by the relative increase in measurements. *Source* Compiled by the authors

Table 1 Complete blood count (CBC) values in GF and HG groups at the end of the reference period, (Mean ± SD)

Indicator	GF	HG
WBC, $\times 10^9$/L	11.18 ± 0.96	11.1 ± 1.09
Lymph, $\times 10^9$/L	6.05 ± 0.98	6.08 ± 0.92
Mon, $\times 10^9$/L	0.96 ± 0.089	0.82 ± 0.126
Gran, $\times 10^9$/L	4.38 ± 0.27	4.2 ± 0.35
RBC, $\times 10^{12}$/L	8.52 ± 0.21*	7.88 ± 0.22*
HGB, g/L	118.6 ± 2.51*	110.75 ± 2.21*
HCT, %	31.48 ± 1.83	30.3 ± 1.02
MCV, fL	38.0 ± 3.21	38.52 ± 1.11
MCH, pg	14.1 ± 0.83	14.17 ± 0.33
MCHC, g/L	373.6 ± 10.41	370.0 ± 6.98
RDW, %	17.16 ± 1.15	16.9 ± 0.23
PLT, $\times 10^9$/L	200.2 ± 24.38	209.5 ± 24.57
MPV, fL	5.48 ± 0.33	5.2 ± 0.39
PDW	15.72 ± 0.29	15.87 ± 0.17
PCT, %	0.1088 ± 0.012	0.1080 ± 0.005

* $p < 0.02$

Source Compiled by the authors

erythrocytes (RBC) and hemoglobin (HGB) in GF foals in comparison with HG foals was revealed in the general clinical blood test (Table 1).

A biochemical blood test at the end of the reference period also revealed significant ($p < 0.05$) differences in Mg and CHOL values. In the GF group, the Mg level was 10.11% higher and the CHOL level was 17.42% lower than in the HG group.

In general, the differences between the groups were not significant and reliable in terms of growth and had small differences in the indicators of the general clinical and biochemical analysis of blood.

4 Discussion

The results of the study showed that weaned foals are well adapted to the consumption of grain-free feed and willingly eat it.

The absence of significant differences in growth rates between HG and GF foals indicates that high fiber grain-free concentrates are fully capable of meeting the high demands of actively growing young. Despite the fact that the content of fiber in the diet of GF foals was more than 133% higher than the norms proposed in the "Norms for feeding and diets for farm animals" (Kalashnikova et al., 2003), no evidence of insufficient energy and nutrient intake due to the depressing effect of fiber was observed in our study. Also, we did not find any signs of insufficient energy and nutrient intake in the results of the analysis of blood samples. The lack of negative

impact of high-fiber diets when replacing grain concentrates with alternative grain-free feeds, when rearing foals of thoroughbred riding breed and half-breed breeds, is described in a number of studies (Mack et al., 2014; Moore-Colyer et al., 2020). Experiments on weaned foals and yearlings have shown that they can effectively use not only grain-free concentrates for normal growth and development, but also diets consisting entirely of voluminous roughage (Jansson et al., 2012; Ringmark, 2014). At the same time, experiments on the use of grain-free concentrates in the rearing of weaned thoroughbred horse breeds, carried out by Ott et al. (2005) showed that foals fed high starch and sugar concentrates had significantly greater rates of weight gain and body length gains than foals fed diets with minimal non-structured carbohydrates (NSC) (Ott et al., 2005).

It should be noted that in our study, HG diets of foals also contained a significant excess of crude fiber relative to the recommended values of the norms we used (Kalashnikova et al., 2003). The content of CF was 54% of the dry matter of the diet. This excess was caused by a sufficiently large amount of eaten hay, due to which an excess was formed by more than 110% exceeding the norm. At the same time, the foals did not have any deviations from normal growth in the studied age period. The dynamics of changes in their measurements corresponded to normal growth rates for foals of a given breed and age. Perhaps the decisive factor in the negative effect of crude fiber is not its actual quantity, but its qualitative composition (the content of neutral detergent and acid detergent fiber) and digestibility. In our study, we did not analyze hay for ADF and NDF, but only for CF. But the hay used throughout the experiment was first cut, of excellent quality and properly stored, which suggests that its fiber had good digestibility.

During the study, foals of the GF group showed significant, higher levels of red blood cells, hemoglobin, and magnesium. For sport horses, high hemoglobin levels within the normal range are desirable, as they provide more efficient oxygen transfer during work (Padalino et al., 2014). Dosed work positively affects the increase in the number of red blood cells and hemoglobin in blood (Bis-Wencel et al., 2011; Krumrych, 2009). There are also studies on the positive effect of certain mineral supplements on increasing hemoglobin levels in horses (Hoffman et al., 1999; Wayne et al., 1984). However, reliable data on the effect of diet or individual types of feed on the change in the values of RBC and HGB indicators in both adult horses and foals have not been published. An increase in hemoglobin and red blood cells was noted in the study by Dynnikova et al. (2020) when adding alfalfa grass meal to the diet of young sports horses. In our work, alfalfa grass meal was also used as the basis of grain-free feed. But it is premature to say that its inclusion in the diet contributes to the improvement of these indicators. Perhaps its composition (minerals, beta-carotene, protein) has a positive effect on hematopoietic functions. But this requires a separate study and additional confirmation.

Among the possible reasons for the higher levels of magnesium in GF could be that the basis of grain-free pellets was alfalfa grass meal, which is considered an available source of this element for the horse (Vervuert, 2008). The magnesium content in the granules was higher (2.7 g/kg) than in the grain mixture (0.4 g/kg) and, accordingly, GF foals received more magnesium from the diet.

The lower cholesterol level in the GF group requires more detailed study, as it may possibly have an impact on the characteristics of energy metabolism in growing foals. Features of the development of microflora in foals on a grain-free diet can be considered as one of the proposed factors for such a decrease. While we did not examine microflora development in GF and HG foals in this study, a number of studies have shown that colon microflora is more diverse and works more efficiently in horses fed grain-free diets with good quality roughage (Daly et al., 2012; Kristoffersen et al., 2016; Sorensen et al., 2021; Willing et al., 2009). Considering that one of the functions of the microflora is cholesterol assimilation (Frape, 2004), it is possible that in our case, the lower content of CHOL in GF is a consequence of its more active use by the microflora.

The rationality of using the grain-free type of feeding of herbivorous farm animals was reflected in the works of a number of researchers back in the 60 s of the last century. For example, the research results of P.D. Pshenichny and A.P. Beguchev showed that feeding animals at an early age of vegetable coarse and succulent feed contributes to their better digestibility and assimilation at an older age (Beguchev, 1963, 1965; Beguchev & Polezhaeva, 1981; Pshenichnyy, 1961, 1966). We assume that similar processes are relevant for foals. And reducing the level of grain concentrates or completely abandoning them is not only a measure to prevent the development of metabolic, orthopedic and other diseases in young animals, but also a tool for the formation of horses with more efficient system for extracting energy and nutrients from roughage for their own needs.

5 Conclusion

The results of the study showed that weaned foals of the Oryol trotting breed quickly get used to and eat grain-free concentrated feed well. Grain-free concentrates, low in starch and sugar and high in fiber, provide the increased energy and nutrient requirements of weaned foals. The growth and development rates of foals on a grain-free diet do not differ from those of foals fed grain concentrates and correspond to normal growth rates for foals of this breed.

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Applied Solutions for Launching Autonomous Agricultural Production Based on AgroTech and Their Contribution to Sustainable Innovation in Agribusiness

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Abstract The purpose of this paper is to identify the contribution of AgroTech to sustainable innovation in agribusiness in the context of the pandemic and the COVID-19 crisis, as well as to develop the applied solutions for launching autonomous agricultural production based on AgroTech to maximize its mentioned contribution. The research is carried out by regression analysis using the example of the top 10 agribusinesses in the Forbes rating of 2021, representing 10 of the world's leading agrarian economies. As a result, the significant contribution of AgroTech to the sustainable (possible growth of 1,515.73% on average) and innovative (possible growth of 6.15% on average) development of agribusiness is justified. The concept was developed and based on the experience of the Sustainable Development Consortium and Technological Leadership, applied solutions were proposed for launching autonomous agricultural production based on AgroTech, which allows maximizing its contribution to the sustainable and innovative development of the agribusiness. The benefits of autonomous agricultural production based on AgroTech are accelerated growth, increased yields, targeted and improved nutritional properties.

Keywords Agribusiness · Autonomous agricultural production · Sustainable development · Innovative development · AgroTech

JEL Codes Q01 · Q12 · Q13 · Q16 · M21 · O32

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https://doi.org/10.1007/978-981-19-3555-8_23

1 Introduction

Agribusiness in 2020–2021 was among those areas of business activity that were seriously affected by the pandemic and the COVID-19 crisis, as it is associated with a large capacity of human resources. Successful experience in high-tech industries has shown that they are much less affected due to a higher degree of automation. In contrast, agribusiness faced a difficult choice. On the one hand, it needs sustainability, which in this study refers to the efficiency of the economic results of entrepreneurial activity (profit, profitable capitalization, etc.) But on the other hand, agribusiness needs innovation to maintain competitiveness and meet the challenges of food security.

This causes the problem of finding opportunities and prospects for a balanced—sustainable and innovative development of agribusiness. This research hypothesises that both the sustainability and innovation of the agribusiness can be ensured by its high-tech development—the transition to AgroTech. The purpose of this paper is to identify the contribution of AgroTech to sustainable innovation in agribusiness in the context of the pandemic and the COVID-19 crisis, as well as to develop the applied solutions for launching autonomous agricultural production based on AgroTech to maximize its mentioned contribution.

2 Literature Review

The foundations of commercially sustainable agribusiness development, as well as its increased complexity in the context of the pandemic and the COVID-19 crisis, are noted in the works of Gras and Hernández (2021), Lang et al. (2021), Neves et al. (2021). The need for innovative development of the agribusiness and barriers to its achievement (such as investment, organizational and managerial) in the context of the pandemic and the COVID-19 crisis are indicated in the works of Adawiyah and Istiqomah (2020), Barth et al. (2021), Dudukalov et al. (2020), Shukla and Sengupta (2021). The benefits of AgroTech as a high-tech agribusiness are highlighted by Morozova and Litvinova (2019), Newar et al. (2020), Podder et al. (2021).

A literature review showed that in past works sustainable and innovative development of agribusiness is studied separately, and a common path for their systemic achievement is not found (gap 1). AgroTech's potential for sustainable and innovative development of agribusiness is poorly understood (gap 2). Existing applied solutions for AgroTech are fragmented and few in number, while theoretical studies of AgroTech dominate (gap 3). The identified gaps in the literature are comprehensively filled in this work.

3 Materials and Method

To test the hypothesis and identify the contribution of AgroTech to the sustainable innovative development of the agribusiness in the context of the pandemic and the COVID-19 crisis, the top 10 agribusinesses of the Forbes rating (2022) for 2021 (Sector: Consumer Staples; Industry: Food Processing) were selected, representing top 10 agricultural economies in the world. The dynamics of their commercial sustainability indicators in 2020–2021 is given in Table 1.

Based on the data from Table 1, sustainability was calculated (percentage change in indicators in 2021 compared to 2020). Also, from the materials of WIPO (2022), statistics of business innovation by countries of the formed sample were taken. Using the method of regression analysis, the influence of high-tech industries share on all these indicators is studied (by WIPO, 2022). The empirical basis of the research is given in Table 2.

Using the least squares method, the maximum possible value of the share of high-tech industries is substituted into the obtained simple (one-factor) regression models—this is how the potential for increasing the sustainability and innovation of the agribusiness, based on AgroTech, is determined.

4 Results

The contribution of AgroTech to the sustainable innovation of agribusiness in the context of the pandemic and the COVID-19 crisis is defined in Table 3.

The results from Table 3 indicate that the share of high-tech industries in the leading agricultural economies of the world (as an indicator of AgroTech) has a positive effect on all indicators of the sustainability and innovation of the agribusiness in 2021. The following potential for increasing the sustainability and innovation of the agribusiness based on AgroTech has been identified:

- Labour productivity growth by 10.72%;
- ICTs and organizational model creation by 1.51%;
- Increase in annual sales growth by 4,063.25%;
- Increase in annual profit growth by 419.19%;
- Increase in annual asset growth by 64.76%;
- Increase in annual capitalization growth by 7.77%.

The results proved the hypothesis and revealed the significant contribution of AgroTech to the sustainability and innovation of agribusiness. To maximize this contribution, it is recommended to launch autonomous agricultural production based on AgroTech, the concept of which is shown in Fig. 1.

Based on experience and experimental development of own “smart” vertical farm of the Sustainable Development Consortium and Technological Leadership

Table 1 The dynamics of indicators of commercial sustainability of the top 10 agribusinesses of the Forbes rating for 2021 in 2020–2021

Place in the ranking (2021)	Name of Agribusiness	Home country of Agribusiness	2020, billion dollars				2021, billion dollars			
			Sales	Profits	Assets	Market value	Sales	Profits	Assets	Market value
436	Kraft Heinz Company	United States	25.2	1.9	104.1	37.1	26.2	0.356	99.8	50.1
238	Danone	France	28.3	2.1	50.9	45	26.9	2.2	52.3	46.4
276	Wilmar International	Singapore	42.6	1.3	47	16.1	50.5	1.5	51	25.9
660	Associated British Foods	Australia	20.3	0.9041	20.5	18.9	17.7	0.5798	21.6	26.5
1,050	Kerry Group	Ireland	8.1	0.6341	10.7	20.3	7.9	0.6317	11.6	23.2
859	Charoen Pokphand Foods	Thailand	17.2	0.5751	21.2	4.8	18.8	0.8123	25.4	7.9
1,115	CJ Corporation	South Korea	29	0.2291	34.9	1.9	27.1	0.0734	36.8	2.6
1,364	Meiji Holdings	Japan	11.5	0.481	9.5	10.1	11.3	0.6019	10.6	9.2
1,275	Saputo	Canada	10.9	0.466	10.2	10.3	10.9	0.4557	10.5	0.13
1,249	Grupo Bimbo	Mexico	15.2	0.3275	14.8	6.8	15.4	0.4219	15.4	9.4

Source Compiled by the author based on Forbes (2022) systematization of materials

Table 2 Indicators of sustainability, innovation and high-tech business in the leading agricultural economies in 2021, %

Country	High-tech manufacturing	Innovation		Sustainability—change in performance in 2021 compared to 2020			
		Labour productivity growth	ICTs and organizational model creation	Sales	Profits	Assets	Market Value
	x	y_1	y_2	y_3	y_4	y_5	y_6
United States	44.9	1.6	83.7	4.0	−81.3	−4.1	35.0
France	51.4	−2.0	70.9	−4.9	4.8	2.8	3.1
Singapore	76.2	−0.3	74.6	18.5	15.4	8.5	60.9
Australia	24.6	−1.2	67.3	−12.8	−35.9	5.4	40.2
Ireland	58.5	−1.3	70.8	−2.5	−0.4	8.4	14.3
Thailand	45.1	−0.1	60.3	9.3	41.2	19.8	64.6
South Korea	59.1	1.1	64.0	−6.6	−68.0	5.4	36.8
Japan	55.1	−2.0	67.8	−1.7	25.1	11.6	−8.9
Canada	37.6	0.2	77.0	0.0	−2.2	2.9	26.2
Mexico	48.9	−2.7	57.9	1.3	28.8	4.1	38.2

Source Compiled by the author based on materials

Table 3 Results of econometric modelling of the contribution of AgroTech to the sustainable innovative development of agribusiness

Indicator of sustainability and innovativeness of the agribusiness	Regression model reflecting the contribution of AgroTech to the sustainable innovative development of the agribusiness	Potential to increase the sustainability and innovation of the agribusiness based on AgroTech (%)
Labor productivity growth	$y_1 = 0.0014*x - 0.7382$	+10.72
ICTs and organizational model creation	$y_2 = 0.0211*x + 68.371$	+1.51
Sales	$y_3 = 0.3762*x - 18.402$	+4,063.25
Profits	$y_4 = 0.6081*x - 37.722$	+419.19
Assets	$y_5 = 0.0841x + 2.2564$	+64.76
Market value	$y_6 = 0.0484x + 28.62$	+7.77

Source Calculated and compiled by the authors

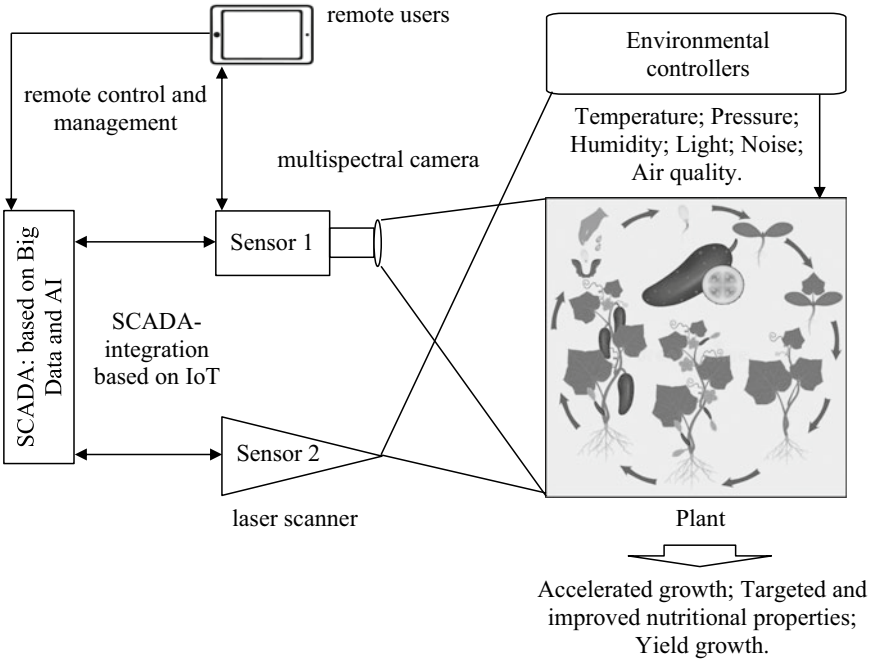

Fig. 1 The concept of autonomous agricultural production based on AgroTech. *Source* Author's Design

offers applied solutions for launching autonomous agricultural production based on AgroTech for practical realization of the concept from Fig. 1:

- Automated management (SCADA) of the "smart" vertical farm based on Big data and artificial intelligence (AI);
- System of open sensors for phytomonitoring (the Consortium is developing its line of low-cost sensors). It includes:
  - Sensor 1: Infrared camera Pi based on Raspberry Pi Zero W (minicomputer with Wi-Fi support). The DIY Infragram filter, which is available in the public domain, enables the analysis of NDVI-type plants using the remote user's phone/tablet/laptop;
  - Sensor 2: A laser scanner that measures, firstly, the vital characteristics of a plant: biomass, height, leaf (fruit) morphology, light penetration and consumption characteristics, disease assessment, aging characteristics, chlorophyll levels, carotenoid levels, levels of organic and inorganic nitrogen. Secondly, environmental indicators: temperature, pressure, humidity, light, noise, air quality (particulate matter analysis);
- SCADA integration based on the Internet of Things (IoT);
- Environmental controllers are automatically controlled by SCADA.

The benefits of autonomous agricultural production based on AgroTech are accelerated growth, specified and improved nutritional properties, as well as increased yields.

5 Conclusion

Thus, the significant contribution of AgroTech to the sustainable (possible growth by 1,515.73% on average) and innovative (possible growth by 6.15% on average) development of agribusiness is justified. The developed concept and applied solutions, based on the experience of the Sustainable Development Consortium and Technological Leadership for launching autonomous agricultural production based on AgroTech, allow maximizing its contribution to the sustainable and innovative development of the agribusiness.

The theoretical significance of the obtained results is the resolution of existing contradiction and justification of the prospects of balanced sustainable and innovative development of the agribusiness based on AgroTech. The practical significance of the authors' conclusions and recommendations is that they can serve as a practical tool for the accelerated and more efficient development of agribusiness in AgroTech.

Acknowledgements The research was carried out within the framework of the Sustainable Development Consortium and Technological Leadership

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Climate-Resilient Agriculture in AgroTech: Advantages for Risk Management of Agrarian Business

Anastasia A. Sozinova

Abstract The goal of this work is to identify the advantages of climate-resilient agriculture in AgroTech for risk management of the agrarian business. To achieve this goal, a sample of countries with different levels of development of climate-resilient agriculture in AgroTech, i.e., with different positions in the Natural Resources and Resilience ranking, has been formed. The regression dependence of each entrepreneurial risk of agrarian business (in isolation) on the development of climate-smart technologies in AgroTech in 2021 has been determined. As a result, it is substantiated that climate-resilient agriculture in AgroTech provides systemic advantages for risk management of the agrarian business, reducing its main entrepreneurial risks. The contribution of climate-resilient agriculture to AgroTech and the reduction of entrepreneurial risks of agrarian business is the highest with land risks, disaster risks, and demographic risks. The practical value of the authors' conclusions and recommendations (proposed optimisation and its supposed advantages) consists in the possibility to use them as a practical guide—in the business practice during risk management of the agrarian business and the practice of state management of the agrarian economy for the practical implementation of SDG 2 and SDG 13.

Keywords Climate-resilient agriculture · AgroTech · Entrepreneurial risks · Risk management · Agrarian business

JEL Codes D81 · G32 · O13 · Q15 · Q16

1 Introduction

Entrepreneurial risks are traditionally considered to be among the highest risks in the agrarian business since they are caused not only by socio-economic factors but also environmental (which are least subject to forecasting and management) factors. Climate change is a serious and global challenge for agriculture, which hinders the

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_24

development of agrarian businesses. All environmental risks of the agrarian business grow under the influence of climate change.

In the aspect of temperature risks, growth of air temperature leads to drought in certain countries, while excessive precipitation causes floods in other countries and growth of sea level and reduction of farmlands area—in other countries. In some countries, quick (from heat to cold, from drought to flood, anomalous heat in summer and anomalous cold in winter) change of weather conditions leads to death of plants and bad harvest.

In the aspect of irrigation (water) risks, climate change leads to unequal and unpredictable precipitation and raises the need for artificial irrigation. In the aspect of land risks, climate change leads to land degradation and depletion (decrease in the fertility) of soil. In the aspect of risks connected to water objects, climate change leads to bogging. Climate change also raises the risks of disasters.

Together with the growth of demand for food and intense urbanization (components of the demographic risks), as well as high general natural risks (large dependence on/intensity of natural resources), the growth of the entrepreneurial risks of agrarian business under the impact of climate change aggravates the problems of food security provision. The following hypothesis is offered: AgroTech allows for the systemic implementation of SDG 2 (provision of food security) and SDG 13 (increasing sustainability towards climate change) in agriculture due to the reduction of entrepreneurial risks.

The purpose of this work is to identify the advantages of climate-resilient agriculture in AgroTech for risk management of the agrarian business.

2 Literature Review

The specific features of climate-smart agriculture—climate-resilient agriculture in AgroTech due to the use of smart technologies as the basis—are noted in the works of the following scholars: Azadi et al. (2021), Chitakira and Ngcobo (2021), Hrabanski and Le Coq (2022), Kassaye et al. (2022), Maleki et al. (2022), Ogunyiola et al. (2022), and Vincent and Balasubramani (2021). Environmental risks of the agrarian business and their growth under the impact of climate change are considered in the works of Chernyshov et al. (2021), Morozova et al. (2019), Popkova and Sergi (2021), Tchernyshev et al. (2019), Zhang et al. (2021), and Zhao et al. (2021).

The overview of the existing research literature has shown a high level of elaboration of the scientific concepts of "climate-smart agriculture" and "entrepreneurial risks of agrarian business" in isolation. However, the interconnection between these concepts has not been described by economic science. The advantages of climate-resilient agriculture in AgroTech for risk management of the agrarian business are not studied sufficiently; they are considered in isolation (in the aspects of risks) and qualitatively. The quantitative treatment of these advantages has not been formed, which is a research gap. This gap is filled in this paper.

3 Materials and Method

The verification of the offered hypothesis is performed with the help of regression analysis. For this, a sample of countries with different levels of development of climate-resilient agriculture in AgroTech—which have different positions in the Natural Resources and Resilience ranking has been formed (The Economist Impact, 2022). Regression dependence of each entrepreneurial risk of agrarian business (in isolation) on the development of climate-smart technologies in AgroTech is determined. The factual basis of the research is presented in Table 1.

Since all indicators have the same measuring units (point) and the same treatment (the higher the values, the better), the advantages of climate-resilient agriculture in AgroTech for the reduction of entrepreneurial risks of agrarian business will be shown by the positive signs of the regression coefficients.

4 Results

The consequences of the development of climate-resilient agriculture in AgroTech for risk management of the agrarian business are reflected by the results of the regression analysis of the data from Table 1 (Table 2).

The results of the regression analysis have shown the following advantages for risk management of agrarian business (regularities of the reduction of risks)—an increase in the level of development of climate-resilient agriculture в AgroTech by 1 point leads to the following:

- Reduction of temperature risks by 0.1633 points: the change of the level of these risks by 42.61% is due to the development of climate-smart agriculture AgroTech;
- Reduction of irrigation risks by 0.65 points: the change of the level of these risks by 61.2% is due to the development of climate-resilient agriculture in AgroTech;
- Reduction of land risks by 0.4007 points: the change of the level of these risks by 63.04% is due to the development of climate-smart agriculture AgroTech;
- Reduction of water objects risks by 0.1003 points: the change of the level of these risks by 42.61% is due to the progress of climate-smart agriculture AgroTech;
- Reduction of general natural risks by 0.0317 points: the connection between the indicators is moderate (correlation equals 6%);
- Reduction of the risks of disasters by 0.7933 points: the change of the level of these risks by 52.64% is due to the development of climate-resilient agriculture in AgroTech;
- Reduction of demographic risks by 0.3883 points: the change of the level of these risks by 30.64% is due to the development of climate-smart agriculture AgroTech.

Based on the obtained regression statistics (from Table 1), the least-squares method is used to perform the optimisation, which demonstrates the potential of

Table 1 Entrepreneurial risks of the agrarian business and climate-resilient agriculture in AgroTech in 2021, points 1–100

Category[a]	Country	Entrepreneurial risks of agrarian business							Climate-resilient agriculture in AgroTech
		Temperature risks	Irrigation risks	Land risks	Water objects risks	General nature risks	Disaster risks	Demographic risks	
		(Temperature) Exposure	Water	Land	Oceans, rivers and lakes	Sensitivity	Disaster risk management	Demo-graphic stress	Early-warning measures/climate-smart Agriculture
Top 3	Norway	79.1	100.0	90.4	19.8	64.4	98.0	68.7	100.0
	Uruguay	73.8	50.0	68.4	11.8	96.8	100.0	84.2	100.0
	Costa Rica	79.2	45.0	86.4	67.3	44.8	100.0	71.2	100.0
Middle 3	Cambodia	65.1	50.0	83.1	28.5	49.7	78.0	83.7	50.0
	Senegal	78.4	0	84.9	16.5	70.9	0	27.2	50.0
	Mali	71.1	0	86.5	41.5	77.1	0	11.4	50.0
Low 3	Indonesia	45.5	0	46.9	19.8	82.7	2.0	69.1	0
	Mozambique	74.2	0	42.2	20.8	45.2	0	16.6	0
	Benin	63.4	0	35.9	28.2	68.6	58.0	21.9	0

[a] By the position in the Natural Resources and Resilience ranking

Source Compiled by the author based on The Economist Impact (2022)

Table 2 Results of the regression analysis

Regression statistics	(Temperature) Exposure	Water	Land	Oceans, rivers and lakes	Sensitivity	Disaster risk management	Demographic stress
Constant	61.811	−5.2778	49.378	23.228	65.106	8.7778	31.028
Coefficient of regression	0.1633	0.65	0.4007	0.1003	0.0317	0.7933	0.3883
Coefficient of correlation	42.61	61.2	63.04	6.54	0.6	52.64	30.64

Source Calculated and compiled by the author

the reduction of entrepreneurial risks of agrarian business at the maximum (100 points) level of development of climate-smart agriculture AgroTech (Fig. 1).

The results of the optimisation (Fig. 1) show that the following could be achieved at the level of the world economy:

- Reduction of temperature risks by 11.67% (down to 78.14 points);
- Reduction of irrigation risks by 119.39% (down to 59.72 points);
- Reduction of land risks by 28.87% (down to 89.45 points);
- Reduction of risks connected to water objects by 17.75% (down to 33.26 points);
- Reduction of general natural risks by 2.38% (down to 68.28 points);
- Reduction of disaster risks by 81.87% (down to 88.11 points);

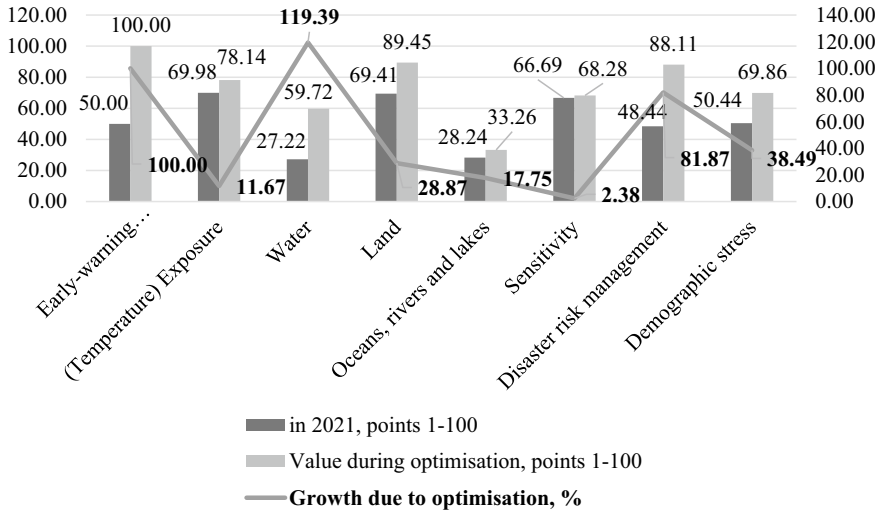

Fig. 1 Potential of the reduction of risks of agrarian business through the development of climate-smart agriculture AgroTech *Source* Calculated and compiled by the author

– Reduction of demographic risks by 38.49% (down to 69.86 points).

5 Conclusion

The results of the research have formed an evidential base, which proves the proposed hypothesis. Climate-resilient agriculture in AgroTech provides systemic advantages for risk management of the agrarian business, reducing its main entrepreneurial risks.

The theoretical value of the results obtained consists in the formation of a comprehensive (systemic) view of the contribution of climate-smart agriculture AgroTech to the reduction of entrepreneurial risks of the agrarian business and the precise quantitative measuring of this contribution. The practical value of the authors' conclusions and recommendations (offered optimisation and its supposed advantages) consists in the possibility to use them as a practical guide—in the business practice during risk management of the agrarian business, as well as in the practice of state management of the agrarian economy for the practical implementation of SDG 2 and SDG 13.

The limitation of the results obtained is the fact that the potential of reducing the entrepreneurial risks in countries that have achieved prominent results in the sphere of the development of climate-smart agriculture is reduced, compared to other countries. Due to this, it is important to search for new perspective technical solutions in AgroTech. Their scientific development should be performed in future technical studies, to enhance the economic results of this work.

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The Mechanism of Innovative Development of Agribusiness Based on AI, Big Data, and IoT for Transitioning to Expanded Reproduction in AgroTech

Lyubov I. Vanchukhina, Inna V. Andronova, Oleg E. Sysoev, and Anastasia I. Smetanina

Abstract This work aims to substantiate the preference of AgroTech for ensuring the expanded reproduction in agriculture and to develop a mechanism of innovative development of agribusiness based on AI, Big Data, IoT for transitioning to the expanded reproduction. To achieve this goal, a sample of nine countries with the lowest values of the crop production index in 2021 is used to find the regression dependence of the index on evolutionary innovation (simple Internet) and on revolutionary innovations: robots controlled by IoT, AI and Big Data. As a result, the vivid potential of the innovative development of agribusiness based on AI, Big Data, IoT and its significant contribution to the increase in reproduction in AgroTech are substantiated. On the other hand, this shows that in case of the absence of a scientifically substantiated mechanism of their use in agribusiness in AgroTech, revolutionary technologies (AI, Big Data, IoT) have a limited contribution (their potential is not fully developed), not allowing for the achievement of the expanded reproduction in agriculture. For the fullest development of the potential of innovative development of agribusiness based on AI, Big Data, and IoT and the achievement of transitioning to the expanded reproduction in AgroTech, an organisational and managerial mechanism has been developed, using the experience of the Consortium for sustainable development and technological leadership.

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E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8_25

Keywords Mechanism of innovative development · Agribusiness · AI · Big Data · IoT · Expanded reproduction · AgroTech

JEL Codes G16 · M15 · M21 · O14 · O32 · Q01 · Q12 · Q13 · Q15

1 Introduction

Expanded reproduction in agriculture is a path to the successful practical implementation of SDG 2 (Zero Hunger). To take this path, it is necessary to ensure the innovative development of agriculture. The problem is that the most accessible and simplest evolutionary innovations (the ones that improve business processes of agribusiness within the applied/unchanged technologies) do not ensure this.

First, low-tech (the most progressive technology at which is the Internet) agricultural production implies a large intensity of land resources, while the attraction of additional volume of these resources is difficult due to their deficit. Second, even with the increase in the resource base (expansion of cultivated areas), an increase in production volume is not guaranteed, since labour efficiency at horizontal farms in open ground is not fixed and is subject to the reduction due to a large number of environmental factors that affect it.

The hypothesis of this research is as follows: achievement of the expanded reproduction in agriculture requires revolutionary (disruptive) innovations: the ones that imply the implementation of new technologies in the agribusiness' activity. AgroTech is hi-tech agriculture. Its end-to-end technologies are AI, Big Data, and IoT. They are thoroughly studied in theoretical science and are adopted in the national strategies of the economy's high-tech development.

However, due to the deficit of applied developments, the scientific view of the mechanism of the practical application of these technologies in the agribusiness' activity has not been formed, which restrains the dissemination and implementation of these technologies in agriculture. The objective of this paper is to substantiate the preference of AgroTech for ensuring the expanded reproduction in agriculture and to develop a mechanism of innovative development of agribusiness based on AI, Big Data, and IoT for transitioning to expanded reproduction.

2 Literature Review

The scientific concept of high-tech agriculture—AgroTech—has been formed and studied in the works of Eck et al. (2020), Newar et al. (2020), and Pandithurai et al. (2017). Certain issues of the use of AgroTech technologies—AI, Big Data and IoT—are elaborated in the works of Bhat et al.(2022), Junaid et al. (2021), Osinga et al. (2022), Popkova et al. (2019, 2021).

Nevertheless, as the performed literature review has shown, it does not offer a complex mechanism of innovative development of agribusiness in AgroTech. Thus,

the perspective of transitioning to expanded reproduction has not been determined. This research gap is to be filled in here.

3 Materials and Method

The proposed hypothesis is tested with the help of regression analysis and comparative analysis. On the example of a specially formed sample of nine countries with the smallest value of the crop production index in 2021 (according to the ranking by the World Bank, 2022), the regression dependence of this index (R_{Agr}) on evolutionary innovations, which is simple Internet (Int), and on revolutionary innovations: robots controlled by IoT (R&IoT), AI and Big Data (AI&BD) form the statistical data by IMD (2022), is calculated.

The proposed hypothesis is considered proved if the coefficients of regression at revolutionary innovations are more significant compared to the coefficient of regression at evolutionary innovations. Since for the result (the reproduction index) "the higher the better" rule applies, and for the factors (positions in the ranking), "the lower the better" rule applies, the positive influence of the factors is shown by the negative values of regression coefficients. The data base of the research is presented in Table 1.

4 Results

The consequences of the innovative development of agribusiness for the reproduction in agriculture are reflected by the following model of multiple linear regression, which describes (mathematically) the results of the factor analysis of the data from Table 1:

$$R_{Agr} = 81.68 - 0.12 * R\&IoT - 0.10 * AI\&BD + 0.28 * Int \quad (1)$$

Model (1) allows for the following conclusions. Evolutionary innovation (simple Internet) does not stimulate the growth of the crop production index. Contrary to it, both considered revolutionary innovations provide this. Thus, an increase in the activity of using robots controlled by IoT by 1 position leads to an increase in the crop production index by 0.10. The growth of the activity of using AI and Big Data leads to an increase in the crop production index by 0.28. The high value of the multiple correlation coefficient (0.7793) is a sign of the close connection between the considered indicators and the reliability of the obtained regression model.

The perspective of transitioning to the expanded reproduction in AgroTech during the innovative development of agribusiness based on AI, Big Data, IoT is reflected by the results of solving the optimisation task on the optimisation of R_{Agr} based on

Table 1 Statistics on innovations and crop research index in 2021

Country	Result	Factors (sources of achieving the result)		
	Crop research index (2014–2016 = 100)	Robots controlled by IoT	AI and big data	Internet bandwidth speed
	Crop production index (2014–2016 = 100)	World robots distribution	Use of big data and analytics	Internet bandwidth speed
	R_{Agr}	R&IoT	AI&BD	Int
Denmark	78.2	29	13	5
Finland	79.3	34	16	30
Lithuania	80.5	46	24	21
Greece	80.5	44	45	49
Latvia	82.5	54	25	24
Germany	83.6	5	53	32
Czech Republic	89	16	38	40
UK	90.7	15	18	39
Argentina	91.5	37	46	55
Arithmetic mean	83.98	31.11	30.89	32.78

Source Compiled by the authors based on IMD (2022), World Bank (2022)

the change of R&IoT and AI&BD in the model (1) with the help of the least-squares method (Fig. 1).

According to Fig. 1, when the highest possible (1st position in the world) activity of the use of robots controlled by IoT (+96.79%) and activity of the use of AI and Big Data (+96.76%) in countries with the lowest value of the crop production index (83.98) is achieved, the value of this index grows by 7.89% (up to 90.60).

On the one hand, this demonstrates the perspectives (vivid potential) of the innovative development of agribusiness based on AI, Big Data, and IoT and its significant contribution to the increase in reproduction in AgroTech. On the other hand, this shows that is there is no scientifically substantiated mechanism of their use in agribusiness in AgtoTech, revolutionary technologies (AI, Big Data, and IoT) make a limited contribution (their potential is not fully developed), not allowing achieving the expanded reproduction in agriculture.

For the fullest realisation of the potential of the development of agribusiness based on AI, Big Data, and IoT and the achievement of transitioning to expanded reproduction in AgroTech in practice, an organisational and managerial mechanism based on the experience of the Consortium for sustainable development and technological leadership has been developed.

According to Fig. 2, the first stage of the developed mechanism is the selection of plants for cultivation. At the first cycle of reproduction in agriculture, these plants

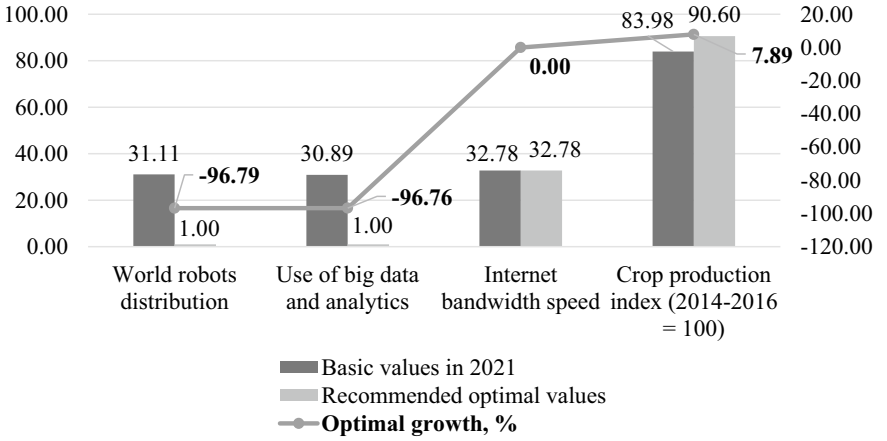

Fig. 1 The perspective of transitioning to the expanded reproduction in AgroTech during the innovative development of agribusiness based on AI, Big Data, and IoT. *Source* Calculated and created by the authors

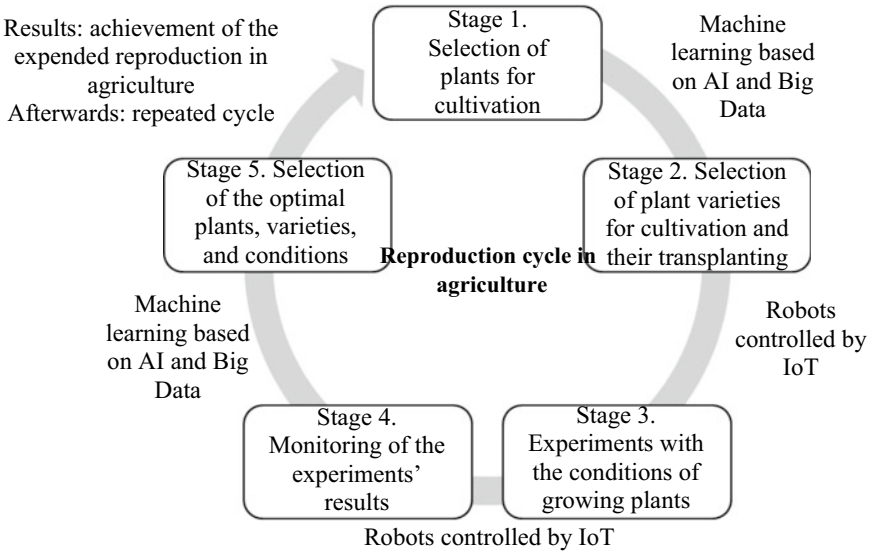

Fig. 2 The mechanism of innovative development of agribusiness based on AI, Big Data, and IoT for transitioning to expanded reproduction in AgroTech. *Source* Developed and created by the authors

and their varieties are selected by the agribusiness managers, and at the recurrent cycles—by machine learning based on AI and Big Data. The second stage implies the selection of plant varieties for growing and their transplanting, which is done by robots controlled by IoT. At the third stage, robots perform experiments with conditions (e.g., fertilisers, lighting, irrigation, etc.) of plant cultivation. The fourth stage is the monitoring of the results with the experience that is performed with the use of machine learning based on AI and Big Data.

At the fifth stage, the optimal plants for cultivation, their varieties, and conditions are collected. The result of the mechanism's work is the achievement of expanded reproduction in agriculture. Then the cycle is repeated many times, which allows accumulating more experience and further increasing the crop production index. The presented mechanism has proved its effectiveness. The Consortium for sustainable development and technological leadership used this mechanism to perform a series of experiments at a smart vertical farm, which allows achieving the expanded reproduction in agriculture in 2021.

5 Conclusion

The obtained results of the economic and mathematical modelling have confirmed the hypothesis that evolutionary innovations (e.g., simple Internet) do not ensure the approach to the expanded reproduction in agriculture. This problem could be solved by revolutionary innovations in AgroTech: AI, Big Data, and IoT. All of them increase the crop production index. The presented mechanism of innovative development of agribusiness based on AI, Big Data, and IoT for transitioning to expanded reproduction in AgroTech has already been tested at a smart vertical farm of the Consortium for sustainable development and technological leadership in 2021.

This paper's contribution to the literature consists in substantiating the hypothesis that the perspective of transitioning to the expanded reproduction in agriculture lies in the sphere of AgroTech and in the formation of a complex view of the most effective use of its technologies, based on the recommended mechanism. The empirical value of the authors' mechanism is that it allows increasing the contribution of agribusiness to the support of SDG 2.

Acknowledgements The research was performed within the Consortium for sustainable development and technological leadership.

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Challenges of the Development of AgroTech in the Decade of Action (Conclusion)

The Decade of Action is the third decade of the twenty-first century (2020–2030), during which the agricultural economy can experience an unprecedented rise due to AgroTech. The conclusions drawn and results obtained based on the research that is performed in this book demonstrate a large potential of AgroTech as a trend of sustainable innovations in agriculture. However, new scientific results that are obtained in this book show the challenges that will be faced by AgroTech in the Decade of Action; the possibility to deal with these challenges will determine the extent of development of the potential of sustainable innovative development of the agricultural economy based on AgroTech.

One of the challenges is the contradiction and instability of the processes of international integration and globalisation. A complex and particular set of production factors in AgroTech could require the development of the global chains of value creation in the agricultural economy. However, the stability of these chains might be threatened due to the destruction of global economic ties.

Another challenge is connected to AgroTech allowing developing highly-efficient agricultural production and satisfying the internal demand for food even in countries where this was impossible due to unfavourable natural and climate conditions. This could cause foreign trade problems for countries that specialise in food export and make them change the direction of the international production specialisation of the economy.

Such challenges include also the social adaptation to AgroTech. The labour market undergoes serious changes. Adapting to them is difficult for employees and employers in the agricultural economy. An important task of modern science is ensuring a crisis-free and conflict-free full-scale transition to AgroTech. The above challenges determine a wide scope for further scientific research of AgroTech. These challenges and the search for perspective answers to them should be the subject of future scientific works on the topic of AgroTech in continuation of this book.

E. G. Popkova and A. A. Sozinova (eds.), *AgroTech*,
https://doi.org/10.1007/978-981-19-3555-8