VERTICAL FARMING AS A FACTOR OF ENSURING FOOD SECURITY IN RUSSIA

Vladimir V. Zemskov[1*], Galina N. Rybalko[1], Valeriy I. Prasolov[1]

[1]Faculty of Economics and Business, Financial University under the Government of the Russian Federation, Moscow, Russian Federation*

[1]Senior Researcher, Institute of Economic Policy and Economic Security Problems (Vladimir V. Zemskov) | Dr. Sci. (Econ.) | ORCID: https://orcid.org/0000-0001-7402-5524 | Email: vvzemskov@fa.ru

[1]Student (Galina N. Rybalko) | ORCID: https://orcid.org/0009-0006-8974-033X | Email: 226102@edu.fa.ru

[1]Candidate of Political Sciences, Associate Professor, Department of Economic Security and Risk Management (Valeriy I. Prasolov) | ORCID: https://orcid.org/0000-0003-0321-4111 | Email: VIPrasolov@fa.ru

*Corresponding Author: Vladimir V. Zemskov, Senior Researcher, Institute of Economic Policy and Economic Security Problems, Faculty of Economics and Business, Financial University under the Government of the Russian Federation, Moscow, Russian Federation | ORCID: https://orcid.org/0000-0001-7402-5524 | Email: vvzemskov@fa.ru

ABSTRACT

Global economic trends indicate a constant search for drivers of growth, which in recent decades has been driven by sustainable development, carbon regulations, and the development of green financing tools. These processes are all based on the ESG approach, which involves effective management of these three components in production.

Compliance with the ESG approach by all stakeholders in managing economic processes ensures stable development, which is essential for achieving economic sovereignty. Food security plays a crucial role in this process, as it forms the basis for society's vital activity and is essential for political consensus between governments, businesses, and society. Food security guarantees stable and progressive development. In order to identify potential threats and risks to food security, a SWOT analysis was conducted and a multifactorial regression analysis was performed based on this.

Keywords: sustainable development; economic sovereignty; self-sufficiency in basic food products; vertical farming; food security.

INTRODUCTION

In recent decades, the world has been facing a number of significant challenges related to food security, including population growth, rapid urbanization, climate change, and the depletion of natural resources. These factors threaten the sustainability of our food systems and have led to the development of innovative solutions such as vertical farming.

Vertical farming is an innovative approach to agriculture that involves growing plants in vertically stacked layers, significantly saving space and resources while minimizing the impact of external factors like climatic conditions and pollution. This method ensures the production of high-quality food and makes it possible to grow more food in a limited area.

As a result, vertical farming has become an increasingly important solution for addressing the challenges of food security and ensuring the availability of healthy food for all. Vertical farming is a significant step in the development of Russia's agricultural sector. It can not only address the challenges of food security in an urbanized environment, but also contribute to environmental sustainability and economic growth.

Various interpretations of the concept of "security" can be found in applied economics. They range from the absence of danger, as defined by the Dictionary of the Russian Language [1] to the state of protection of vital interests of the state, society, and individuals from internal and external threats, as described by Bykov B.A. [2]. A generalized definition of security can be considered as ensuring the protection of legally recognized values, according to the Basic Model for Determining Criteria and Categories of Risk [3].

Next, we turn to the concept of "food security". When we analyze Russia's regulatory documents on food security, we find that there have been continuous refinements and changes to the regulatory process regarding the understanding and importance of food security in achieving strategic objectives. According to the 2020 Russian Food Security Doctrine[4], food security is considered a main direction of strategic development that ensures the "food independence" of the Russian Federation, meaning self-sufficiency in key agricultural products and physical and economic access to food products meeting mandatory requirements for every citizen in volumes not lower than the rational consumption norms necessary for an active and healthy lifestyle (Decree of the President of the Russian Federation [4].The level of self-sufficiency in basic food products, according to the Food Security Doctrine, is:

grain – not less than 95%;
meat and meat products – not less than 85%;
milk and dairy products – at least 90%;
fish and fish products - not less than 85%;
potatoes – at least 95%;
vegetables and melons – at least 90%;
fruits and berries - at least 60%.

The issue of food security has become increasingly significant due to factors such as climate change, decreasing availability of traditional agricultural land, and population growth. These challenges necessitate the introduction of innovative solutions like vertical farming in order to ensure sustainable food production.

In recent years, the Russian economy has been developing successfully, especially the agricultural sector. In 2024, compared with 2015, the production of agricultural enterprises increased by 3070.5 billion rubles, or 2 times. The production of peasant (farms) also saw an increase by 776.7 billion rubles, or 2.5 times. Figure 1 illustrates the trends in agricultural enterprise and peasant farm production for 2015–2024 [5].

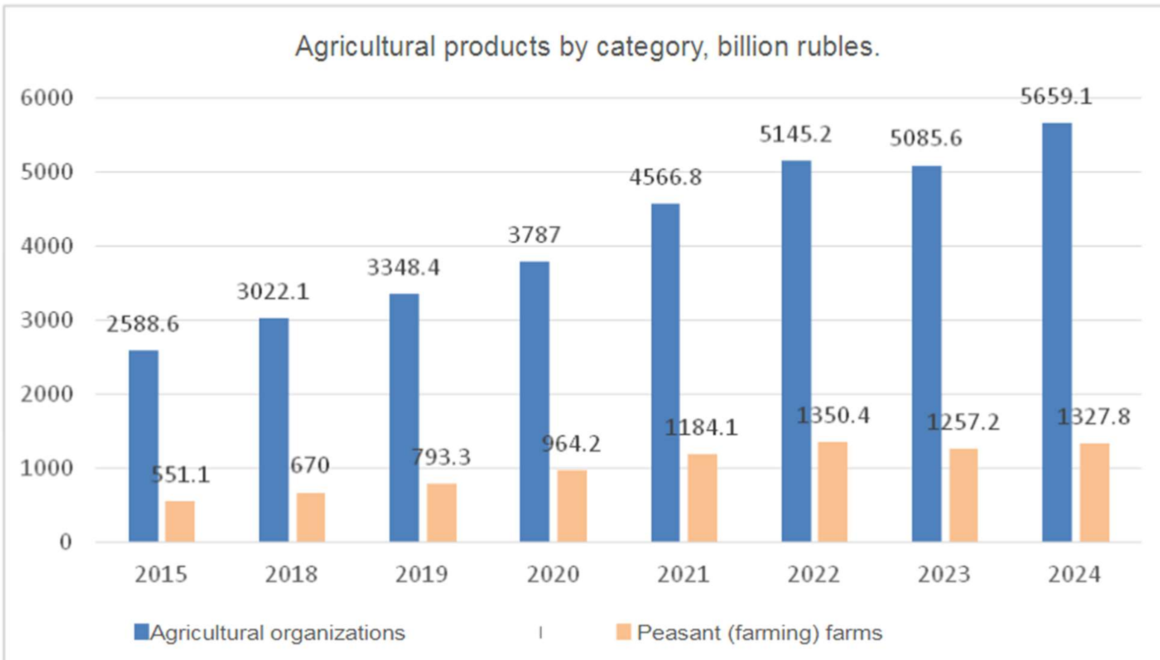

Fig.1 Agricultural products by category

The main risk factors that have contributed to the positive development of agriculture include:
- the formation of modern infrastructure;
- government support in the form of concessional loans;
- ensuring employment in agriculture and increasing wages.

Another indicator of food security is the level of self-sufficiency in basic food products. This indicator characterizes a country's ability to produce enough food for a healthy standard of living. *Figure 2* shows the dynamics of the level of self-sufficiency in basic food products for 2015, 2018–2024 [5].

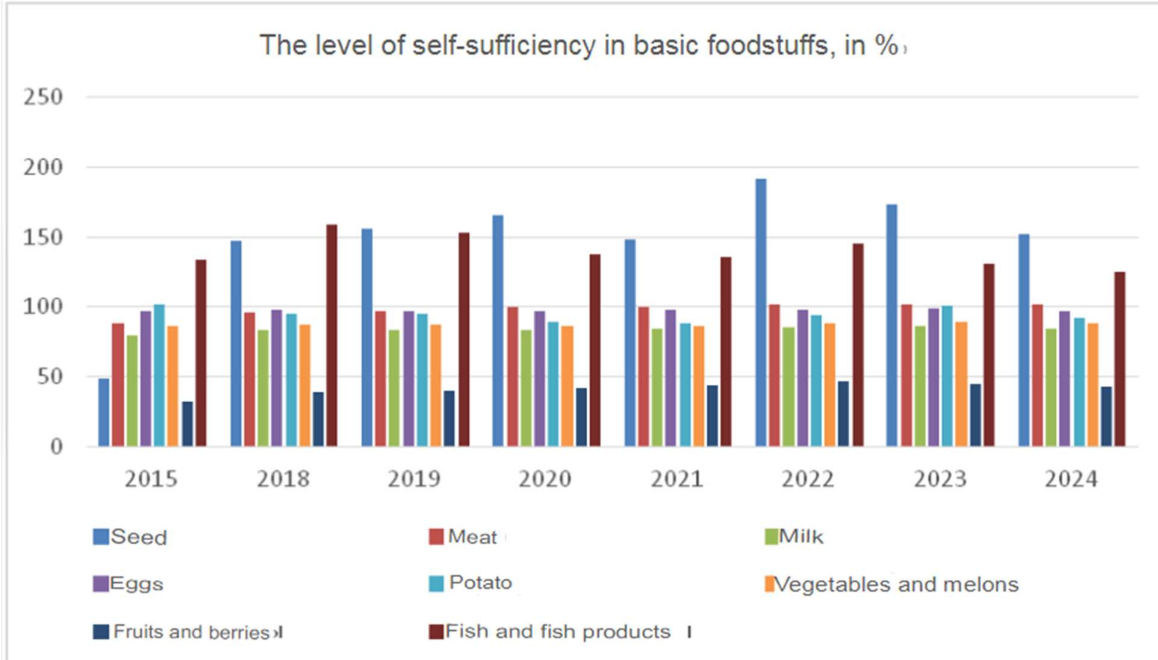

Fig.2. The level of self-sufficiency in basic foodstuffs

As can be seen in *Fig*.2, in 2024, the level of self-sufficiency in basic food products does not meet the targets for certain food items:

milk - 85.7%,

vegetables and melons - 88.5%,

fruits and berries – 47.3%.

Vertical farming offers a wide range of products, including more than 30 types of vegetables and herbs such as salads, spinach, basil and strawberries. This diversity is achieved due to the possibility of precise control of growing conditions, which makes it possible to adapt the process to the needs of different crops.

The aim of this study was to form a scientific hypothesis regarding the potential use of modern digital technologies in the agricultural sector, particularly in agriculture, for the production of crops that promote a healthy lifestyle. In order to achieve this goal, several objectives were set and achieved:

- research of the theoretical foundations for the use of modern digital technologies in the production of crop products for a healthy lifestyle [6, 7, 8];
- assessment of the peculiarities of vertical farming development in foreign practice [9];
- substantiation of the vertical farming development model in Russia [10, 11].

The social impact of vertical farming is manifested in a change in the approach to food production and consumption. Such farms create new jobs in cities, raise public awareness of sustainable development issues, and provide access to fresh produce.

The results of the study can be used in the practical activities of peasant (farming) farms in the organization of vertical farming.

1. PROBLEM STATEMENT

As noted above, in 2024, the level of self-sufficiency in such types of products as milk, vegetables, melons and berries does not meet the targets, which indicates the presence of unresolved problems in the production of these types of agricultural food.

One of the modern technologies for the production of crop products is minimal tillage [12, 13, 14]. Here, the main approach may be the introduction of vertical farming, the essence of which is the cultivation of crop products (greens, cucumbers, mushrooms, berries) in vertical farms using modern digital solutions for monitoring irrigation, temperature, and soil microanalysis [13]. The use of this technology makes it possible to grow any type of crop in a limited space while reducing labor costs, which ultimately ensures high yields and production efficiency [15, 16, 17].

Before beginning the cultivation process, it is important to determine the appropriate OKVED codes for the specific activity. These codes indicate the type of activity and are used to form the tax base for each activity. According to the All-Russian Classifier of Activities, vertical farming can be categorized under the following OKVED codes:

- OKVED 01 - Crop and livestock production, hunting, and related services
- OKVED code 01.13 - Cultivation of vegetables, melons, root crops, tubers, mushrooms, and truffles

Japan and Singapore are considered to be pioneers in crop cultivation technology due to several factors. Firstly, there is a lack of available land in these countries, which has led to the development of innovative methods for growing crops. Secondly, the majority of people live in urban areas, which creates a demand for efficient farming techniques that can be applied in limited spaces. Thirdly, food shortages have driven innovation in crop production.

Currently, the most modern technologies for food production are aquaculture, hydroponics, aquaponics and vertical farming [18, 19]. As you know, aquaculture is the process of cultivating fish resources in artificial ponds. Hydroponics, on the other hand, is a technique for growing plants without the use of soil. Aquaponics, meanwhile, involves the cultivation of both fish and vegetables in a single container. According to specialists of the Japanese company Miral, *"modern technological systems allow producing 10,000 heads of lettuce per day"* [18, 19]. The most popular technologies for growing crops are urban farms [20].

In 2021, the Singapore National Welfare Fund launched a pilot project for the installation of vertical farms at bus stops. The project aims to harvest butterhead lettuce, bok choy, and gai lan in a volume of up to 100 kilograms over the course of one year. By 2030, Singapore aims to provide 30% of its food needs independently.

Examples of successful international projects demonstrate the potential of vertical farming to solve global food problems. One of the most impressive is the Dubai farm, which produces 2,700 kilograms of vegetables daily, which significantly meets the needs of the local population.

According to the Agroinvestor magazine, *the global vertical farming market is expected to reach $4.3 billion by the end of 2021 with an average annual growth rate of 25.5%.* [21].

And how are things in Russia? Russia is starting to take only the first steps in vertical farming. According to Rosselkhoznadzor experts, "By 2030, the market volume may reach 33 billion dollars.USA" [21]. The main vertical production facilities are mainly located in Moscow, where green and vegetable crops, berries and mushrooms are grown.

2. RESEARCH METHODOLOGY

Based on the data from the reports of the United Nations International Telecommunication Union and the Food and Agriculture Organization, we have compiled a comparative description of digital solutions in agriculture in selected countries around the world (see *Table 1*). [18].

Table 1.

Indicators of Digital Agriculture Indices by Individual Countries as of 2020

Country	Opinion poll of the leaders of the World Economic Forum (max -7)	The global competitiveness index "Government's Future Orientation" (max -7)	Competitiveness Index
Azerbaijan	5.24	4.72	20
Kazakhstan	4.65	4.13	39
Russia	4.83	3.87	54
Tadjikistan	4.46	4.46	27
Türkiye	3.38	3.82	64
Ukraine	4.43	2.98	115
Moldova	4.43	2.99	114

The business processes of vertical farming are aligned with the trends of the new development model based on the ESG approach and the regenerative economy. The main distinguishing features of this model include:

- a culture of responsible consumption and environmentally friendly production;
- recycling of consumption and production waste, or the introduction of a closed-loop economy;
- creation of additional high-quality jobs in areas where a circular economy is emerging.

The data in *Table 2* confirm the hypothesis that vertical farming can produce environmentally friendly products. This study provides a comparative analysis of the effectiveness of modern crop-growing technologies [18].

Table 2

Comparative Characteristics of the Effectiveness of New Technologies in the Cultivation of Agricultural Crops

Name of the technology	Crop Yield level, in %	Maturation rate, in %	Water consumption, in %
Aeroponics	130	150	10
Hydroponics	110	120	30
Traditional farming	100	100	100

As can be seen from the data presented above, modern aeroponic and hydroponic technologies are significantly more efficient than traditional agricultural methods and align with the principles of ESG and regenerative economics [22].

Lighting, temperature, and humidity are controlled using automated systems, minimizing human intervention and improving overall production efficiency. These systems enable year-round production, which is crucial in a changing climate. Research suggests that vertical farming can significantly enhance resource efficiency in urban environments, making it a promising solution for food security.

During the research, publicly available scientific methods were used, including analysis, synthesis, comparison, content analysis, and SWOT analysis. Regulatory documents and legal frameworks of the Russian Federation related to food security were also consulted. Additionally, scientific papers by both foreign and domestic researchers were reviewed, along with relevant information provided by experts in the fields of environmental protection and natural resource management.

3. RESULTS

Vertical farming in Russia is a relatively new sub-branch of crop production that has both advantages and disadvantages, including potential threats and risks. *Table 3* presents the results of a SWOT (strengths, weaknesses, opportunities, and threats) analysis of this type of farming in Russia.

Table 3.

SWOT Analysis of Vertical Farming in Russia

Strengths	Weaknesses
No need for arable land Influx of personnel from traditional crop production Carbon neutrality Products belong to the category of environmentally friendly ones, free from harmful substances No expenses for the purchase of mineral fertilizers, fuels, and lubricants Year-round cultivation of crops Rational use of water resources for irrigation Minimum logistics efforts during product transportation Reduction in product maturation time	Grown products may not contain all the essential trace elements that humans need. The insurance costs for production facilities and electricity capacities are higher. There is a lack of qualified personnel, particularly IT specialists. Drilling artesian wells incurs additional costs. Operating an artesian well also involves additional expenses, such as obtaining a license for mineral resource use, checking water quality, and state accounting for the well. Permissive urban planning documentation is lacking for the construction and operation of vertical farms. Vertical farms are not eligible for state support measures for agriculture.
Opportunities	**Threats**
Using financial instruments of “green technology” To increase the level of self-sufficiency in vegetables and berries Diversification of activities in order to ensure the continuity of business processes Additional jobs (agronomists, microbiologists, IT specialists)	Technological accidents on power grids can lead to damage (crop losses, power equipment failure) Violations of accounting standards in the organization of separate cost accounting between types of activities Penalties imposed by regulatory authorities in the taxation of various types of products

The current legislation in the field of agriculture in Russia primarily focuses on traditional farming methods, which presents challenges for the implementation of innovative techniques such as vertical farming. Additionally, there are no clear regulations or standards governing this type of operation, which hinders its development and integration within the country’s agricultural industry.

In order to assess the impact of the identified threats in *Table 3* on the country’s food security, we will examine each threat in detail.

For example, technological accidents on power grids are a significant concern. The main cost of vertical farming is electricity, and so we will focus on this aspect.

Let’s *take the case of the farm of Agritecture, which has an area of approximately 2.800 square meters and is located in the suburbs of New York. This farm spends at least $216.000 per year on lighting and electricity alone*.[1]

In the process of producing products, accidents, power surges, and power equipment failures can occur, which can lead to damage. Who is responsible for this? Let’s turn to paragraph 1 of Article 38 of the Federal Law on the Electric Power Industry No. 35-FZ, which states that: “*Electric power industry entities that supply electricity to consumers, including energy market organizations, guaranteeing suppliers, and territorial grid organizations, are responsible for ensuring reliable and quality electricity supply to consumers in accordance with technical regulations and other mandatory requirements*”.

Threats of Violations of Accounting Standards When Organizing Separate Cost Accounting Between Types of Activities

The Accounting Regulation “Accounting Policy of the Organization” (Accounting Regulations, 1/2008) requires separate accounting for costs, income, and expenses, as well as input VAT (application of different

[1] Do we need city farms in Russia? URL:https://dzen.ru/a/YsLCLwklyTI1oav6

taxation regimes), in the event of significant changes in activities. In this case, it is necessary to develop a separate accounting methodology and include it in the accounting policy.

As an example, let's take the activities of PJSC Magnit. The company engages in both trading and crop production (vertical farming), and therefore requires separate accounting methods for these two activities.

Vertical farming makes extensive use of advanced technologies, including LED lighting, which reduces energy consumption, and closed-loop water systems, which provide resource-saving solutions. Hydroponic and aeroponic systems allow for the cultivation of plants without the use of soil, making it possible to establish farms in urban environments such as rooftops or specially designed spaces.

The methodology of separate cost accounting in vertical farmers

Separate cost accounting in vertical farming is becoming increasingly important due to the development of the Russian agriculture sector and the need for financial and tax transparency. In this type of farming, which is characterized by high technological costs and specialized operations, clear accounting methods allow not only for improved internal management but also for compliance with tax regulations that mitigate financial risks [23].

Without separate accounting, organizations are deprived of the ability to deduct VAT and expenses related to the unified agricultural tax [23]. This is a significant issue, especially for vertical farmers who may incur additional operational costs while introducing innovative technologies and equipment.

The separate accounting methodology should include categories that allow you to reflect both VAT-eligible and non-VAT transactions. This makes it possible to extract significant benefits when executing government orders funded from the budget. When using targeted funds, this accounting structure ensures control over the expenditure of allocated funds. At the same time, it should be borne in mind that violations in keeping separate records may lead to the risk of improper use of subsidies, which may qualify as taxable income.

Vertical farming often involves multiple stages and different types of operations, such as exports and domestic supplies, which emphasizes the need for separate accounting. Using separate accounting allows for detailed income and expense tracking in various areas, which is essential for assessing the profitability of individual units and optimizing costs.

It is also important to consider that separate accounting allows for more accurate determination of time differences for taxation and reduces the likelihood of accounting errors, while meeting the requirements of current regulations.

If a farm begins selling both consumption-oriented and export-oriented products, maintaining separate records becomes even more relevant.

Therefore, the methodology for separate accounting in vertical farms should be based on clear principles that take into account the specificities of accounting in agriculture and comply with tax regulations. This will not only help avoid potential tax penalties, but also create a stable financial structure that supports economic security in vertical farming.

Vertical farming in Russia is emerging due to the increasing demand for sustainable and efficient food production. It can significantly improve food security, especially in remote regions where climatic conditions are changing and access to fresh vegetables is limited. This is particularly true in the Far East, where transportation costs are often high and logistical problems hinder the delivery of fresh food. The use of high-tech vertical farming techniques can significantly reduce transportation costs and increase the availability of fresh produce for local populations. As China's experience shows, the use of high technology makes it possible to achieve the efficiency of the food supply chain. [24].

The popularization of urban farming in Russia is opening up new opportunities for improving food security. It provides potential locations for local food production in cities, where space is often limited. Vertical farming, which uses small areas, offers a way to obtain a quick and high-quality harvest in the center of the city. This maximizes the use of urban land for agricultural purposes, which has a positive impact on the economy and environment of the city.

Vertical farms have the ability to control growing conditions and harvest, leading to improved product quality. This ensures freshness, safety, and reduces the amount of pesticides and fertilizers in food. Automation technologies allow for monitoring of resources, making the production process more efficient and environmentally friendly compared to traditional agriculture [25].

Although vertical farming in Russia is still in its infancy, there is a promising trend towards its development. The sector is expected to grow significantly by 2030, with the potential to produce 20.000 tons of products, which would significantly increase self-sufficiency and reduce dependence on imports.

However, the implementation of these projects faces several challenges. One of the main obstacles is the high level of investment required, which can be risky for small producers. Additionally, the vulnerability to power outages necessitates the search for alternative energy sources, adding complexity and increasing costs. Furthermore, the lack of developed infrastructure and accounting standards makes cost separation difficult, which is crucial for successful business operations in this field.

Despite these challenges, the positive trends in vertical farming indicate a promising future for this sector in Russia. With continued support and investment, it is possible to overcome these obstacles and achieve success in the long run.

It is essential to develop a system for supporting and funding vertical farms, which not only will increase the number of producers but also create new job opportunities. This, in turn, would contribute to improving the quality of life for the population by providing fresh food and nutrition for local communities. It is important that public policy supports this innovative formula for active participation in the global movement towards sustainable agriculture and food security [26].

The analysis of threats of violation of accounting standards is presented in *Fig.3*

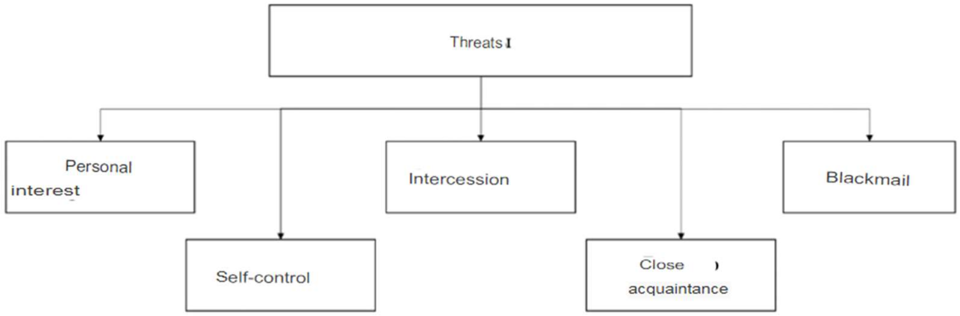

Figure 3. Analysis of threats of violation of accounting standards.

Given the growing interest in vertical farming in Russia, it is important to take into account the risks associated with accounting and reporting standards. This area of the agricultural sector, unlike the traditional one, requires more innovative approaches to cost management and control. At the same time, the implementation of the principles of separate cost accounting becomes a key factor in ensuring the accuracy of financial statements.

Speaking about specific accounting problems in the agricultural sector, there are several main challenges. Violations of accounting policies are at the top of the list, as incorrect wording can lead to significant distortions in financial results. Accountants working in vertical farms must be attentive to the wording of their accounting policies to avoid distortions that could lead to penalties and dissatisfaction from stakeholders.

The disharmony between accounting and tax accounting adds complexity, especially when dealing with the new regulations of the Tax Code. If these systems are not integrated well, it can lead to errors in expense calculations or underestimation of tax liabilities, which can cause dissatisfaction from regulatory authorities. This requires accountants to not only follow the rules strictly, but also have a deep understanding of their specific reporting requirements.

Additionally, it's worth noting the increasing stringency of reporting requirements. Errors in compiling and presenting accounting information can result in repeated inspections by government agencies and substantial financial losses for companies. Accountants should not only be aware of current regulations but also prepared for changes in reporting legislation, especially in rapidly growing industries like vertical farming.

The accounting process in agricultural enterprises can become more complex due to changes in legislation. These changes require constant study of new regulations and standards, which can lead to incorrect interpretation and potential errors. These errors can create additional risks for businesses.

In such circumstances, the work of accountants becomes more challenging, requiring not only professional knowledge but also analytical skills. This is especially true in vertical farming, where even small errors can have a significant impact.

Among the types of errors common in agribusiness accounting, it is worth mentioning the lack of timely formation of accounting policy. This can lead to a lack of necessary data for proper cost allocation, which is especially important for vertical farms, where a variety of technologies and production approaches require a detailed analysis of each stage. To minimize risks, enterprises must constantly review their accounting policies, improving them in accordance with current legal requirements and internal management standards.

In conclusion, setting up accounting processes in vertical farming requires a comprehensive approach. Accountants should not only have the technical skills necessary to maintain accurate reporting, but also show critical thinking and flexibility to effectively adapt to changes in legislation and market requirements. This will ensure more reliable cost control mechanisms and minimize financial risks.

Threats of penalties from regulatory authorities in the taxation of various types of products.

According to expert estimates, Russia has 2 million mandatory requirements, the government's cost of verifying them is 1.5% of GDP, and businesses face an additional 6% burden from complying with these requirements.

Meanwhile, the agro-industrial complex has significant potential for growth. According to the Federal Tax Service, it accounts for 10.5% of the total weight of the Russian economy in terms of officially registered jobs, 3.1% in terms of value added, and 1.68% in terms of enterprises.

A comparative analysis of traditional farming and vertical farming reveals the unique characteristics of each method. Traditional farming, with its rich history, relies on classical methods such as agronomy and biotechnology. Modern technologies like IoT sensors allow farmers to effectively monitor growing conditions and yields, but this approach faces challenges related to sustainability and environmental impact.

Unlike traditional methods, vertical farming offers a novel solution for efficiently using limited resources. With a 70% reduction in water consumption compared to conventional farming, it is attractive for modern megacities, which can grow vegetables and fruits in urban settings. However, there are drawbacks such as high initial investments in equipment and the need for artificial lighting and heating, as well as labor costs, which significantly increase overall costs.

However, vertical farming also has some drawbacks. The high initial investment in equipment, the need for heating and artificial lighting, and the high labor costs all significantly increase overall costs. This requires farmers to be innovative and prepared for the risks associated with the high levels of investment, compared to the traditional approach.

The significance of vertical farming increases due to the rising urban population and demand for food [27]. It can serve as a dependable source of fresh produce and adapt quickly to changing customer needs. The market for vertical farming is projected to reach $35 billion by 2032 [28], indicating increasing interest from investors and entrepreneurs.

Thus, the differences between traditional and vertical farming are reflected not only in technology, but also in economic models, ecosystem approaches, and strategies aimed at ensuring food security. Each of the approaches deserves attention and in-depth study, which can lead to a synergistic effect within the framework of sustainable agriculture.

In addition, vertical farming contributes to a significant reduction in environmental pollution. Traditional agriculture often results in pollution of water sources with fertilizers and pesticides. However, in vertical farms, these issues are minimized thanks to closed water circulation systems and controlled growing conditions.

After identifying the strengths and weaknesses of vertical farming, we will create a list of vertical farming businesses, based on which we will perform a multifactor regression analysis (see *Table 4*).

Table 4

List of Vertical Farming Businesses in Russia as of October 2025

№	Company name	Registration number	OKVED Code
1.	JSC “LOCAL ROOTS”	1207700300500	01.13.1; 01.63; 46.31; 72.11; 72.19; 47.21
2.	“AGROASPECT PLUS” LLC	1186658064614	01.13; 01.13.1; 01.13.11; 01.13.12; 01.13.2; 01.13.3; 72.11
3.	“ATF” LLC	1196658022989	72.19; 01.13; 01.25.1; 01.25.2; 46.31.1; 47.21
4.	“VERTICAL FARMS” LLC	1205400011080	01.63
5.	“VERTICAL FARMS” LLC	1197746737924	72.19; 01.13; 46.31; 47.21
6.	“URBAN GREENHOUSES” LLC	1175476101844	72.19; 01.13; 01.13.4; 46.31; 47.21
7.	“CITY FARM” LLC	5187746026705	01.13; 01.13.12; 01.13.4; 01.25; 47.21
8.	“CITY FARM” LLC	1183668029280	01.63; 01.13; 01.21; 01.22; 01.23; 01.24; 01.25; 46.31
9.	“AGRICULTURAL TECHNOLOGIES OF THE FUTURE” LLC	1142723003356	01.13.1; 01.29; 10.39; 10.39.1; 10.39.2

Source: compiled by the authors based on data from the Interfax news agency

As can be seen from Table 4, vertical farming in Russia is a relatively new sub-sector of agriculture, and a number of selected businesses carry out various activities. However, the share of revenue from sales of agricultural products in this sector is insignificant (less than 5%). Therefore, for the purposes of this research, all financial indicators were fully accepted.

Initially, we chose the following model for regression analysis:

$Y_t = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon_t$ (1),

Where Y_t – average thresholds for fruits and berries, vegetables; X_1 - aggregated revenue for 9 selected companies; X_2 - aggregated cost of sales for 9 selected companies; X_3 – aggregated cost of fixed assets for 9 selected companies; X_4 – aggregated cost of inventories for 9 selected companies; X_5 – aggregated accounts receivable for 9 selected companies.

Since the Food Security Doctrine indicates thresholds for food independence as a percentage and the accounting statements reflect indicators in thousands of rubles, standardization was performed.

The standardization algorithm is as follows:

The thresholds are calculated as the ratio of domestic production to domestic consumption. Therefore, to obtain the planned value of domestic production for the studied years, it is reasonable to multiply the actual domestic consumption of vegetables, fruits, and berries in 2020–2024 by the corresponding thresholds (90% for vegetables and 60% for fruits and berries). The results are presented in *Table 5*.

Table 5

Planned Values of Domestic Production (in kg)

	2020	2021	2022	2023	2024
Fruits and berries (kg)	5413140000	5483280000	5556600000	5797440000	5697900000
Vegetables (kg)	14109660000	13663980000	13759200000	13834800000	13937940000

Source: compiled by the authors on the basis of data from the Federal State Statistics Service.

Further, the indicators from the natural value must be converted into monetary form. For this, consumer price indices for goods by fruit and vegetable groups for 2020–2024 were used. The standardization results are presented in *Table 6.*

Table 6.

Planned Values of Domestic Production (in Thousand Rubles)

	2020	2021	2022	2023	2024
Fruits and berries	611143506	564229512	593444880	746130528	640443960
Vegetables	1693159200	1679303142	1307124000	1620055080	1778481144

Source: compiled by the authors on the basis of data from the Federal State Statistics Service.

After that, using the arithmetic mean formula, we can calculate the average production value for fruits, berries, and vegetables.

$$\overline{V} = \frac{V_{dom.prod.(fruits\ \&berries)} + V_{dom.prod\ (veg)}}{2} \quad (2),$$

Where $V_{dom.prod.(fruits\ \&berries)}$ – the volume of domestic production of fruits and berries, $V_{dom.prod.veget)}$ – the volume of domestic vegetable production.

As a result of calculations, the following values were obtained:

Y_{2020} = 1152151353 thousand rubles;

Y_{2021}= 1121766327 thousand rubles;

Y_{2022} = 950284440 thousand rubles;

Y_{2023}= 1183092804 thousand rubles;

Y_{2024}= 1209462552 thousand rubles.

The data used for linear regression (1) is presented in *Table 7.*

Table 7.

Multiple Linear Regression Data (in Thousand Rubles)

	Y	X1	X2	X3	X4	X5
2020	1152151353	227839	205770	101949	97952	42381
2021	1121766327	495231	316643	79954	108920	120800
2022	950284440	663203	429570	80089	102107	160214
2023	1183092804	312098	215417	68812	144308	226883
2024	1209462552	362355	225795	70105	26843	51518

Source: compiled by the authors

Based on the results of the statistical analysis of the data using the LINEAR function in Excel, some of the variables were eliminated from the model, as they were not significant. The sequential addition method was used to identify the variables that best fit the model. As a result, the multiple regression model was reduced to three variables.

$Y_t = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon_t$ (3),

Where Y_t –average thresholds for fruits and berries, vegetables; X_1- aggregated cost of sales for 9 selected companies; X_2 - aggregated revenue for 9 selected companies; X_3 - aggregated cost of fixed assets for 9 selected companies.

First, let's examine the correlation between the indicators. To begin, we will assess the strength of the relationship between Y and X1 (*Figure 3*)

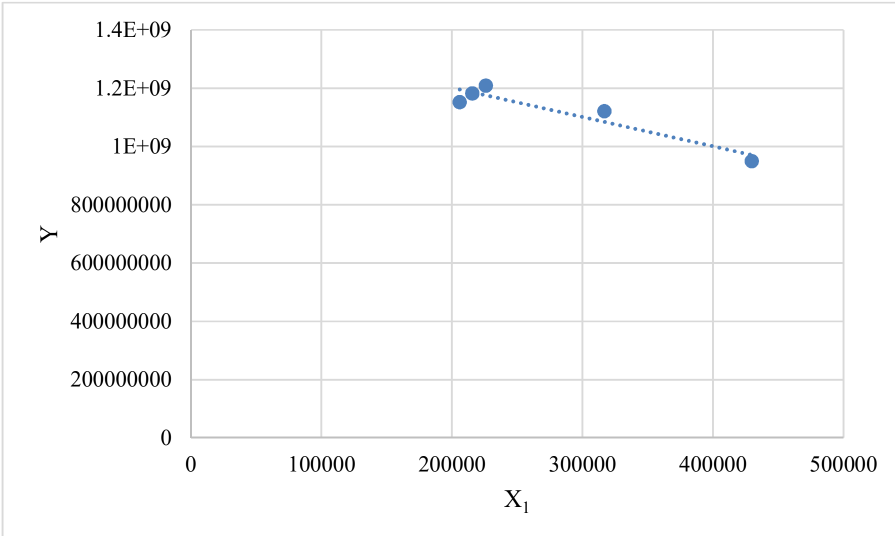

Fig. 3. Correlation field between *Y* and X_1

As can be seen in *Figure 3*, the point spread is minimal, indicating a close relationship between *Y* and X_1. The downward movement of the trend line suggests the presence of an inverse relationship.

Let's now look at the relationship between Y and X_2 in *Figure 4*.

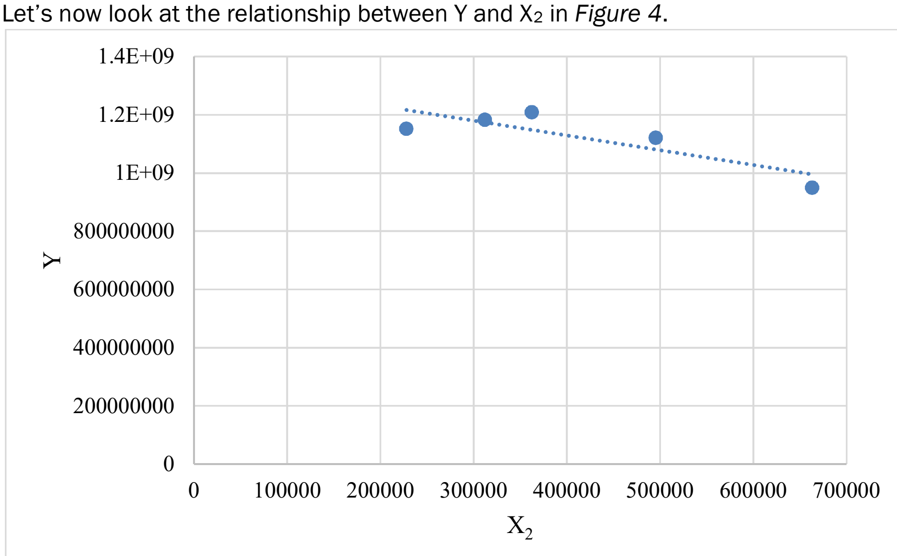

Fig. 4. Correlation field between *Y* and X_2

In *Figure 4*, you can see small deviations from the trend line, therefore, the relationship between *Y* and X_2 is not as strong as between *Y* and X_1, but it is also reversed, since the average line tends downward.

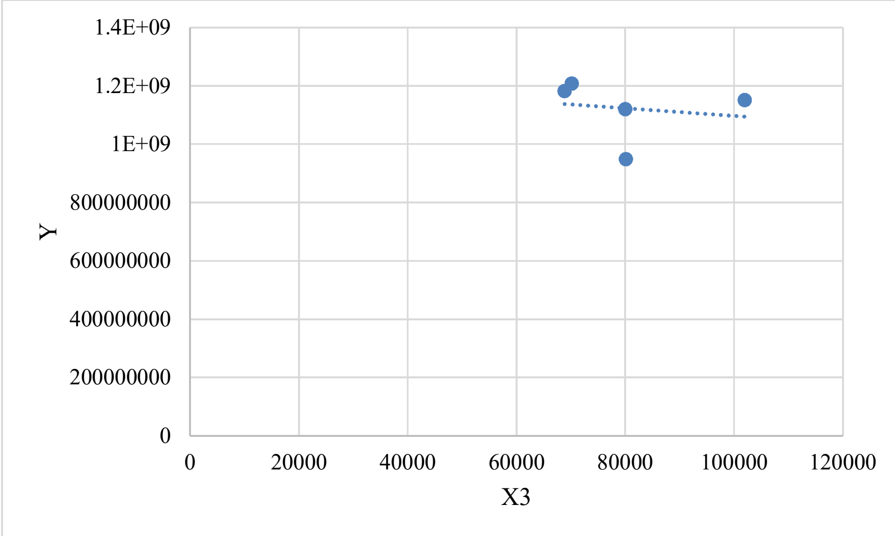

Fig. 5. Correlation field between *Y* and X_3

Figure 5 shows a fairly strong spread, which tells us about a weak feedback between *Y* and X_3.

Let's consider the statistical relationship between the exogenous and endogenous variables in *Table 8.*

Table 8

Correlation Between Regressors and the Endogenous Model Variable

	Y	X_1	X_2	X_3
Y	1			
X_1	-0.939831948	1		
X_2	-0.848402009	0.975628122	1	
X_3	-0.166564468	-0.070660983	-0.266640924	1

Source: compiled by the authors

As you can see, there is a strong feedback between *Y* and X_1, as well as between *Y* and X_2. The factors X_1 and X_2 have a strong direct relationship. There is no relationship between *Y* and X_3, similarly for factors X_1 and X_3 and X_2 and X_3.

Let's estimate the parameters of the multiple regression model (3) and write out the result in standard form:

$$Y_t = 1347451836 - 3610.96X_1 + 1502.03X_2 + 2032.89X_3 + \varepsilon_t \ (4).$$

(90283664.95) (881.5) (509.67) (1440.89)

Thus, the base value of the average thresholds for fruits and berries, vegetables (*Y*) is 1347451836 thousand rubles, with a change (increase) in the aggregated cost of sales for 9 selected companies (X_1) by 1 thousand rubles. *Y* will decrease by 3610.96 thousand rubles, with a change in the aggregated revenue for 9 selected companies (X_2) by 1 thousand rubles. (*Y*) will increase by 1502.03 thousand rubles, and if the aggregated cost of fixed assets for 9 selected companies changes (X_3) by 1 thousand rubles. (*Y*) will increase by 2032.89 thousand rubles.

Table 9.

Regression Statistics Results

Regression Statistics Indicators	Meaning
Multiple *R*	0.996785504
R square	0.993581342
Normalized *R* square	0.974325368
The standard error	16373648.35
Observations	5

Source: compiled by the authors

Let's look at these results in more detail.

The multiple *R* is 0.9968, which indicates a strong relationship between the exogenous and endogenous variables. The quality of the resulting regression (*R* squared). The result is 0.9936, which means that the model explains the dependencies well.

Since regression is multiple, it is important to consider the normalized R-square, which takes this into account, it is 0.9743, which also indicates that the model is adequate.

The standard error is 16373648.35, which is acceptable in our case, given the magnitude of the *Y* values.

Based on the results of the regression analysis, it can be concluded that there is a strong relationship between the financial performance of business entities engaged in vertical farming and food independence (Multiple R = 0.9968), referring to the correlation between regressors and the endogenous variable (r_{yx1} = –0.9398; r_{yx2} = –0.8484; r_{yx3} = –0.16656), then a decrease in the cost of sales and an increase in revenue leads to the achievement of thresholds for food independence for fruits and berries, vegetables in Russia, which confirms the scientific hypothesis of an increase in the level of self-sufficiency for these crop products.

CONCLUSION

In conclusion of our study, it can be confidently stated that vertical farming is one of the most promising strategies for ensuring Russia's food security in the face of modern challenges such as a growing population, urbanization and limited resources. Foreign researchers also confirm the relevance of the development of vertical farming in the form of the development of appropriate clusters [29,30, 31,32].

The study revealed that vertical farming is an innovative and promising approach to addressing food security in the context of increasing urbanization and climate change. It allows for the efficient use of limited urban spaces, reduces transportation costs, and minimizes environmental impact.

In analyzing the current trends in vertical farming in Russia, we have found that this approach to agriculture not only meets the demands of modern society but also opens up new opportunities for the sustainable development of the agricultural sector.

Vertical farms using advanced technologies such as hydroponics, aeroponics, and process automation have the potential to significantly increase the production of fresh, high-quality food, which is essential in light of the limited availability of land and the need to reduce carbon emissions.

The impact of vertical farming on Russia's food security is significant. It not only helps to meet the increasing demand for safe and high-quality food, but also improves the availability of fresh produce in cities, where traditional agriculture is faced with serious challenges. Vertical farms can be located in close proximity to consumers, which reduces logistics costs and delivery time, as well as minimizes product losses. This, in turn, contributes to improving food security, as it allows us to provide the population with fresh food all year round.

The development of vertical farming is expected to significantly improve Russia's food security. With their year-round production and efficient resource utilization, vertical farms can significantly reduce the country's dependence on food imports. Reducing transportation costs and minimizing environmental impact makes production more sustainable and environmentally friendly. In the long run, this will ensure a stable supply of fresh food to the population, regardless of climate conditions and seasonality.

However, despite the many advantages, vertical farming does face some challenges related to compliance with accounting standards. An analysis of the risks of violating accounting rules when implementing separate cost accounting has revealed that insufficient transparency in financial transactions can lead to inefficient resource management and a reduction in overall business profitability.

It is important to emphasize that separate cost tracking between different activities in vertical farming is crucial for understanding the financial health and efficiency of the business. Our research emphasizes the need for a clear method for separate accounting that will not only enhance financial reporting but also increase investor and partner confidence.

Multivariate regression analysis has also revealed several key differences that could influence the choice of business strategy. For example, vertical farming typically requires smaller areas of land, making it more suitable for urban areas. Additionally, the use of modern technology can significantly reduce water and fertilizer consumption, making this approach more environmentally friendly.

However, traditional farming also has advantages, such as lower initial investment costs and the ability to utilize natural resources. The examples of successful vertical farming projects in Russia, which were reviewed in this study, demonstrate that this approach is not only viable but also profitable.

Despite existing barriers such as the high cost of technology and a lack of regulatory framework, the prospects for the development of vertical farming in Russia remain significant. The combination of innovative technologies and government support can take the industry to a new level.

Vertical farming offers unique opportunities for cities facing challenges of population growth and limited land availability. Multi-tiered systems allow for efficient utilization of vertical space, which is particularly relevant in densely populated areas. These farms can be located within buildings or on rooftops, converting unused areas into productive zones. Not only does it reduce cities' dependence on rural supplies, but it also reduces transportation costs and the carbon footprint.

Thus, vertical farming not only addresses the challenges of food security but also presents new opportunities for sustainable development of the agricultural sector in Russia. Considering all these aspects, we can say with confidence that vertical farming has the potential to play an important role in the country's food system, contributing to improved quality of life and food independence.

REFERENCES

1. Russian Dictionary: in 4 volumes – vol. 1 / edited by A. P. Evgenieva. Moscow: Russian language : Polygraph Resources, 1999.

2. Bykov B. A. Ecological Dictionary. Moscow: Nauka, 1988.

3. The basic model for determining criteria and categories of risk (approved by the minutes of the meeting of the Project Committee dated 31.03.2017 No. 19(3)) (together with the "Requirements for substantiation of risk categories (hazard classes) and risk criteria proposed by federal executive authorities participating in the priority program "Reform of Control and Supervisory activities" in relation to their activities types of state control (supervision)").URL: https://www.consultant.ru/document/cons_doc_LAW_222112/d9b60a6f9c29fd22806353ffcb06166fb3522ec2 / (date of access: 02/06/2026).

4. Decree of the President of the Russian Federation dated 01/21/2020 No. 20 "On Approval of the Food Security Doctrine of the Russian Federation". URL: http://government.ru/docs/all/125815 / (date of reference: 02/06/2025).

5. Agriculture in Russia.2024: Stat.sat./Rosstat, Moscow: 2023, p.103.

6. Zmushko A.A., Kirchenko A.V. Vertical farms as a new trend in agriculture. Fruit Growing. 2023;35(2):199-205. (In Russ.) https://doi.org/10.47612/0134-9759-2023-35-199-205.

7. Gaiardelli, P., Pezzotta, G., Rondini, A., Romero, D., Jarrahi, F., Bertoni, M., Wiesner, M., Wuesten, T., Larsson, T., Zaki, M., Jussen, Ph., Boucher, X., Bigdeli, A. Z., Cavalieri, S. Product-service systems evolution in the era of Industry 4.0 // Service Business. 2021. Vol. 15. P. 177–207. https://doi.org/10.1007/s11628-021-00438-9.

8.Nadkarni S., Prügl R. Digital transformation: a review, synthesis and opportunities for future research // Management Review Quarterly. 2021. Vol. 71. P. 233-241. https://doi.org/10.1007/s11301-020-00185-7.

9.Kobayashi Noriaki. Sustainably growing society supported by food. Toward the establishment of a «smart food system». Brochure SIP «Pioneering the Future: Japanese Science, Technology and Innovation 2019». URL: https://www8.cao.go.jp/cstp/panhu/sip_english/p60-61.pdf.

10. Nesterenko N., Pakhomova N., Richter K. K. Sustainable development of organic agriculture: strategies of Russia and its regions in context of the application of digital economy technologies // St. Petersburg University Journal of Economic Studies. 2020. V. 36, No 2. P. 217-242. https://doi.org/10.21638/spbu05.2020.203.

11. Vereshchagina E. I., Galustova E. A. Integration of vertical urban agricultural farms into the building structure of large cities // Bulletin of the Volgograd State University of Architecture and Civil Engineering. Series: Construction and Architecture. — 2024. Issue 1(94). pp. 246-247.

12. Yanova E.A., Orlova O. Yu., Patanina K. V., Boitsova Yu. S., Alenin I. P. Statistics and trends in the development of the vertical farming market // Bulletin of the Altai Academy of Economics and Law. - 2020. — No. 12. — pp. 657-658.

13.Kalyanam T. S. The Environmental Impact of Urban Agricultural Technologies Determined Using Life Cycle Assessment Method–A Systematic Review:diss. – Hochschule Rhein-Waal, 2024.

14. Liu J. et al. Sustainability of vertical farming in comparison with conventional farming: A case study in Miyagi Prefecture, Japan, on nitrogen and phosphorus footprint //Sustainability. – 2022. – Vol. 14. – №. 2. – P. 1042.

15.Soh C. B. et al. Smart Modular Vertical Farms: Addressing Food Security and Resource Efficiency in Singapore's Urban Environment //Horticulturae. – 2026. – Vol. 12. – №. 3. – P. 271.

16. Kluczkovski A. et al. Urban vertical farming: innovation for food security and social impact? //Philosophical Transactions of the Royal Society B: Biological Sciences. – 2025. – Vol. 380. – №. 1935.

17. Stiles W. A. V. et al. The future of vertical farming: necessary advances in precision technology, crop selection and market sector development //The Journal of Horticultural Science and Biotechnology. – 2025. – Vol. 100. – №. 5. – pp. 637-649.

18. Kuznetsov I.V. Development of new technologies in agriculture in Japan /I.V.kuznetsov. – Text: direct //A young scientist. -2023. –№ 2 (449). – P.64.67. – URL: https://moluch.ru/archive/449/98870 / (accessed on 06.02.2026).

19. Keerthana N. S. et al. A robust decision framework for vertical farming using integrated objective weighting and distance driven ranking approach: NK Suganthi Devi et al //Scientific Reports. – 2025. – Vol. 15. – №. 1. – P. 40869.

20. Podolskaya T.V., Vasyuta E.A., Plaksina A.Y. Vertical farms as a key area of agricultural intensification in the context of urbanization // Economics: yesterday, today, tomorrow. 2023. Volume 13. No. 5A. pp. 294-304.

21. Agroinvestor. [Electronic resource] // https://www.agroinvestor.ru/

22. Rajashekar V. et al. The rise of vertical farming: a critical examination of its role in achieving food security and sustainability //Hydroponics: The Future of Sustainable Farming. – New York, NY: Springer US, 2024. – P. 295–309.

23. How agricultural companies keep separate records [Electronic resource] // www.glavbukh.ru - Access mode: https://www.glavbukh.ru/art/388108-kak-selhozkompanii-vesti-razdelnyy-uchet .

24. Fu H., Zhao C., Cheng Ch., Ma H. Blockchain-based agri-food supply chain management: case study in China // International Food and Agribusiness Management Review. 2020. V. 23, No 5. pp. 667–679. https://doi.org/10.22434/IFAMR2019.0152.

25. Grudneva A.A. Vertical farming as an innovative technology for solving the problem of food supply in large cities // Innovations and investments. 2018. № 9. URL: https://cyberleninka.ru/article/n/vertikalnoe-fermerstvo-kak-innovatsionnaya-tehnologiya-resheniya-problemy-prodovolstvennogo-snabzheniya-krupnyh-gorodov (accessed on 01.03.2026).

26. Kostyukova K.S. Digitalization of agriculture in Japan THE WORLD (Modernization. Innovation. Development). 2020. Vol. 11. No. 4. pp. 358-369.

27. Al-Chalabi M. Vertical farming: Skyscraper sustainability? // Sustainable Cities and Society. 2015. Vol. 18. pp. 74–77, https://doi.org/10.1016/j.scs.2015.06.003

28. Mikhailova I. The beds grow upwards. Vertical farms expand into regions Agroinvestor magazine website URL: https://www.agroinvestor.ru/markets/article/39141-gryadki-rastut-vverkh-vertikalnye-fermy-rasshiryayut-ekspansiyu-v-regiony/ (accessed on 06.02.2025).

29. Castells M. The Informational City: Economic Restructuring and Urban Development. - The Wiley-Blackwell, 1992. – 416 p.

30. Doloreux D., Shearmur R. Maritime Clusters in Diverse Regional Contexts: The Case of Canada // Marine Policy. – 2009. – № 3. – pp. 520-527.

18. Claudio R., Riccardo V. Foresight and Innovation in the Context of Industrial Clusters: The Case of Some Italian Districts // Technological Forecasting & Social Change. – 2008. – № 6. – p. 817-833.

31. Feser E. J., Bergman E. M. National Industry Cluster Templates: A Framework for Applied Regional Cluster Analysis // Regional Studies. – 2000. – № 1. – p. 1. – doi: 10.1080/00343400050005844.

32. Porter M.E. The Economic Performance of Regions // Regional Studies. – 2003. – № 6-7. – p. 549-578. – doi: 10.1080/0034340032000108688.

Information about the authors
Vladimir Zemskov – ORCID: 0000-0001-7402-5524.
Galina Rybalko - ORCID:0009-0006-8974-033X,
Valeriy Prasolov, _ ORCID: 0000-0003-0321-4111.